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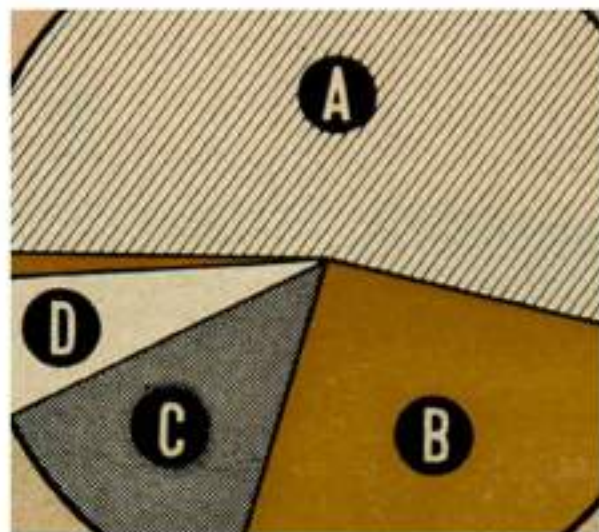
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THE SAMPLE FROM THE ASTEROID BENNU ACQUIRED BY NASA'S OSIRIS-REX MISSION PHOTOGRAPHED BY NASA/ERIKA BLUMENFELD AND JOSEPH AEBERSOLD IN JANUARY 2024

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FOR THE DIY GUYS

Everyone has aging pains, but CBD can help

By: Beth Giles

Life really does fly by. Before I knew it, my 50s had arrived, and with them came some new gifts from dear ol' Mother Nature—frequent knee pain, stress, low energy and sleeplessness. Now, I'm a realist about these things, I knew I wasn't going to be young and springy forever. But still, with "golden years" nearly on my doorstep, I couldn't help but feel a little cheated. That is until I found my own secret weapon. Another gift from Mother Nature.

It began a few months back when I was complaining about my aches and pains to my marathon-running granddaughter, Jen. She casually mentioned how she uses CBD rub to help with her joint pain. She said that CBD gave her more focus and clarity throughout the day and that her lingering muscle and joint discomfort no longer bothered her. She even felt comfortable signing up for back-to-back marathons two weekends in a row this year. That made even this self-proclaimed skeptic take notice.

But I still had some concerns. According to one study in the *Journal of the American Medical Association*, 70% of CBD products didn't contain the amount of CBD stated on their labels. And, as a consumer, that's terrifying!

If I was going to try CBD, I needed to trust the source through and through. My two-fold research process naturally led me to Zebra CBD.

First, I started calling my family and friends. Call me old-fashioned but I wanted to know if there were people whom I trusted (more than anonymous testimonials) who've had success using CBD besides my granddaughter.

Secondly, I wanted cold hard facts. Diving deep into the world of CBD research and clinical studies, I came across Emily Gray M.D., a physician at the University of California at San Diego (UCSD) Medical School and medical advisor to Zebra CBD who is researching the effects of CBD. Dr. Gray wrote "early results with CBD have been promising and we have a lot of research underway now. I've had several patients using CBD with good success. It's important that you know your

source of CBD and how to use it properly."

After hearing it from the doctor's mouth, I returned to my research, asking more people and was amazed by the number of close friends and family who were already on the CBD train. Apparently, I was the only one without a clue! And funny enough, a couple of friends who commented were using the same brand as my granddaughter—Zebra CBD. There was no consensus as to why they were using CBD, but the top reasons given were for muscle & joint discomfort, mood support, sleep support, stress and headaches, as well as supporting overall health & wellness.

Eventually, even the most skeptical of the bunch can be won over. With a trusted CBD source in mind, I decided to give it a go.

When I viewed Zebra CBD's selection online, I was impressed by its array of products, including CBD oils called tinctures, topicals, chewable tablets, mints and gummies. After reading on their website that all their products are made with organically-grown hemp, I ordered... and it arrived within 2 days!

The first product I tried was the Rub. Now this stuff was strong. Immediately after rubbing it on my knee, the soothing effects kicked in. It had that familiar menthol cooling effect, which I personally find very relieving. And the best part is, after two weeks of using it, my knee pain no longer affected my daily mobility.

The Zebra Sleep Gummies, on the other hand, had a different but equally positive effect on my body. To take it, the instructions suggest chewing thoroughly. This was simple enough, and the taste was, well, lemony. After about 15 minutes, a sense of calm came over my body. It's hard to describe exactly; it's definitely not a "high" feeling. It's more like an overall sense of relaxation—and then I fast asleep. Needless to say, I slept great and woke up refreshed. I haven't slept like that in a long time.

While it hasn't been a catch-all fix to every one of my health issues, it has eased the level and frequency of my aches. And it sure doesn't seem like a coincidence how rejuvenated I feel.

All in all, CBD is one of those things that you have to try for yourself. Although I was skeptical at first, I can safely say that I'm now a Zebra CBD fan and that I highly recommend their products.

Also, I managed to speak with a Zebra CBD spokesperson willing to provide an exclusive. If you order this month, you'll receive \$10 off your first order by using promo code **"PM10"** at checkout. Plus, the company offers a 100% No-Hassle, Money-Back Guarantee. You can try it yourself and order Zebra CBD at ZebraCBD.com/PM or at 1-888-762-2699.



Can't Stop Thinking About

THE ANCIENT LANGUAGE OF EASTER ISLAND

+ TODAY, HUMANS INHABIT—OR HAVE, AT the very least, explored—pretty much every corner of the planet. But that immense proliferation of *Homo sapiens* across the globe was a slow process. With the first humans leaving Africa between 60,000 and 120,000 years ago, the species slowly spread across the Earth over many millennia. And one of the last places these ancient humans made their way to was the southeastern Pacific island of Rapa Nui, known more broadly as Easter Island.

Located 2,360 miles off the coast of Chile, Rapa Nui is one of the most isolated places in the world. Its native people, who are also named the Rapa Nui, first arrived on the island's shores between A.D. 1150

Can't Stop Thinking About

and 1280, and lived in isolation until the arrival of Dutch navigator Jacob Roggeveen in 1722.

While Europeans eventually discovered the impressive moai statues for which the Rapa Nui are best known, they also stumbled upon a yet-undeciphered script known as Rongorongo—a three-dimensional writing system that uses pictorial signs known as glyphs.

But because this script wasn't first described until 1864, archaeologists and historians have since pondered an enduring question: Did the Rapa Nui independently invent this language, or were they influenced by Europeans?

Now, a new study is attempting to solve this linguistic conundrum by suggesting that, according to radiocarbon dating, one of the 27 wooden objects containing Rongorongo inscriptions predates the arrival of Europeans, at around 1495 to 1509. This finding suggests that the Rapa Nui could've possibly invented Rongorongo independently—a rare feat throughout human history, and one usually associated with complex states.

The other strong piece of evidence for this homegrown language theory is that Rongorongo functions much differently than European languages, which would appear to suggest no discernible outside influence. Lead author Silvia Ferrara, an archaeologist and linguist at the University of Bologna, Italy, published her team's

findings in *Scientific Reports* in early February.

"The question is of crucial importance, as it implies the possibility of an independent invention of writing, similarly to what happened in other parts of the world where writing was an original creation, e.g., in Mesopotamia, Egypt, China and Mesoamerica," the paper reads. "If Rongorongo predates the arrival of external travelers, it could represent another, and the latest, invention of writing in human history."

While one of the four wood tablets examined provides pre-European evidence for the language, the discovery also comes with a few caveats. For one, radiocarbon dating can only detect when a tree was cut down, not inscribed—though, Ferrara suggests that centuries-old wood would be unsuitable for such a task. But, more important, the wood tablet provides only a sample size of one, as the other examined tablets all fell on the other side of the European divide.

To gather further evidence, Ferrara would have to examine the other remaining tablets, which are all that is left of the long-forgotten language. But they've been scattered across the globe, and are not easy to access. For now, the search continues in the effort to place the contributions of these native people in the correct historical context. —Darren Orf

ALL THE TREASURE WE'VE FOUND

Experts have uncovered a lot of important finds in the recent past. Here's a selection of some of the most exciting.



ALEXANDER THE GREAT

Surveyors discovered a miniature bronze portrait of Alexander the Great, in a Danish field, dated to A.D. 200.

HOLY GRAIL SHIPWRECK

Underwater remotely operated vehicles will soon start recapturing some of the sunken treasure from the San José galleon, dubbed the "holy grail" of shipwrecked treasures. Even conservative estimates have placed the worth of the ship's bounty at billions of dollars.

GEORGE WASHINGTON

A renovation project at George Washington's Mount Vernon mansion uncovered two sealed glass bottles full of cherries, complete with stems, pits, and their signature scent.

RAMSES II STATUE

In 1930, German archaeologists uncovered the lower half of a massive statue of Ramses II. Now, U.S. and Egyptian archaeologists have announced the discovery of the long-missing top half in pristine condition. —D.O. and Tim Newcomb

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The Existence of Wigner Crystals

PHYSICISTS FROM PRINCETON UNIVERSITY have confirmed that electrons don't even need atoms in order to party together. By using magnetic fields, the researchers were able to induce and detect Wigner crystals—orderly assemblies of electrons.

To create and examine a Wigner crystal structure, the scientists used a powerful magnetic field around a readied sample of graphene. Graphene is a preparation of carbon atoms that's just one atom thick, which gives it properties that make it a highly prized tool in the study of microscopic and quantum phenomena. It can be flat, rolled into tubes, wrapped around things, and—in this case—arranged in a

double layer. When the magnetic field was applied, each carbon atom's four electrons were put into play and formed triangular Wigner crystals.

"Wigner predicted that when the Coulomb interactions between electrons become much stronger than their kinetic energy, electrons crystallize into a closely packed lattice," the researchers wrote in the study. Coulomb interactions are a cornerstone of all electromagnetic study, and are also called electrostatic force. They're why the same side of magnets repel each other, and in this case, same-charged electrons repel each other.

When electrons are trapped very tightly within a magnetic field that they can't escape, it's like the car crusher at your local junkyard. The electrons desperately want to flee from each other, but they have nowhere to go. The best they can do is to space out as far as they can, which results in a uniform arrangement—each electron wants to seek out the closest location with the least competition from magnetic forces.

By turning the magnetic field all the way up and turning the temperature all the way down to the cryo zone, researchers were able to observe how this lattice formed—and even photograph the triangular crystals.

The real star of the study may be the scanning tunneling microscope (STM) used to observe this behavior, which allows researchers to "photograph" phenomena on a quantum level without using light. Light is a particle that acts like a wave, and it's disruptive in many nanoscopic contexts. The STM instead works almost like quantum-level radar—a very precise point made from a conducting material is brought very close to the surface it's measuring, and the way in which the current travels back to the tip is what is used to generate imagery.

These images are the first to ever capture this elusive Wigner crystal state. "There are literally hundreds of scientific papers that study these effects and claim that the results must be due to the Wigner crystal, but one can't be sure, because none of these experiments actually see the crystal," senior author Ali Yazdani explained in a statement.

Moving forward, scientists can explore and try to photograph these phase changes and other interesting quantum behaviors using their dual-layer graphene setup (a major darling of quantum research). After that, other researchers may be able to branch into different materials and contexts, with an example in hand of what isolated Wigner crystals may look like. —*Caroline Delbert*



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The End of the Maya Kingdom

A TEAM OF ARCHAEOLOGISTS DISCOVERED clues from between A.D. 733 and 881 that they say represent a key turning point in Maya rule—and a very public one at that.

The discovery at the Maya site of Ucanal in Guatemala “marked a public dismantling of an old regime”—a rather pivotal moment in the collapse of rulers and a key point in a shift in political power, the team wrote in a study published in the journal *Antiquity*.

The event in question occurred at the capital of the K'anwitznal kingdom near a burial site. The bodies and their ornaments—items include a jewel-adorned stone mask, fragments of a greenstone diadem, and jade ornaments—were moved from a tomb to a public burning site, where fire engulfed some of the centuries-old items for all to see.

“This event marked a moment of change in the kingdom and in the lowlands,” the scientists wrote. “Rather than examine this fire-burning event as a bookend to Maya history, we view it as a pivot point around which the K'anwitznal polity reinvented itself, and the city of Ucanal went on to a flourishing of activities.”

The new leadership regime welcomed a non-royal leader called Papmali, who appears to have ushered in an era of prosperity. Substantial construction occurred in various sectors throughout

the city following the power shift.

That new era may have had a dramatic beginning.

The team discovered the fire event in 2022 during excavations of the construction fill of a temple-pyramid situated in a public plaza, and the evidence shows that there was no effort to protect the burial deposit. The team believes that at least four adults were part of the burn remains, and that the fire reached a temperature of over 800°C. Included with the bodies were 1,470 fragments of greenstone pendants, beads, plaques, mosaics, and large blades—all representing a “single burning event.” The quantity and quality of the burnt and broken ornaments indicate that they came from a royal tomb, likely belonging to multiple individuals.

The authors state that the event “appears to have been an act of desecration: It was dumped at the edge of a crude wall used as a construction pen and no effort was made to protect the fragmented bones and ornaments from the tomb blocks deposited on top of them as construction fill.”

“It could dramatically mark,” they wrote, “the dismantling of an ancient regime.” —T.N.



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Synching Up Our Circadian Rhythms

IF YOU'VE EVER DONE ANY KIND OF LONG-distance travel, or just woken up feeling under-rested thanks to daylight saving time, you know how important your circadian clock is. But you might not know that you technically have more than one.

Like many things in your body, your circadian rhythm is more complicated than it might seem on the surface. Rather than being entirely brain-based, it's actually controlled by a collection of several circadian clocks (central and peripheral) that all work together to keep your gears turning like a well-oiled machine.

And much like the gears of a machine, circadian clocks tend to work best when they're in sync. In fact, scientists now think aligning your body's various circadian clocks could help fight the effects of premature aging. The results of two studies on

the matter were recently published in the journals *Science* and *Cell Stem Cell*.

"It is fascinating to see how synchronization between the brain and peripheral circadian clocks plays a critical role in skin and muscle health, while peripheral clocks alone are autonomous in carrying out the most basic tissue functions," Aznar Benitah, PhD, one of the authors of both studies, said in a press release.

The *Science* study focused on muscles and the effects of circadian clock synchronization on musculature. Through their analysis, the researchers found that if your main clock and muscle clock get out of sync, it can lead to signs of premature aging and wasting of the muscle tissue.

The team also found that a dietary practice known as time-restricted feeding (TRF)—requiring that you eat only during the phase of your day in which you are active—can help keep those clocks synched up, reducing the risks of that muscle deterioration. It can also, reportedly, help the muscle clock function better on its own, even without the help of the central clock.

The *Cell Stem Cell* paper, on the other hand, focused on the interactions between the main circadian clock and the circadian clock associated with your skin. Similar to the muscle-focused study, the skin study found that keeping the clocks in sync was important for fighting signs of premature aging.

Interestingly, the team also found that if the clocks were not in sync, the main clock would take over regulation of the skin but would carry out its usual processes on an "opposite" schedule. In the press release, the team uses the example of DNA replication. Usually, if everything is going to plan, DNA replication mostly happens at night when it is less subject to radiation from the sun that could potentially cause mutations. But if the central clock dominates the skin's behaviors, DNA replication would mostly happen during the day.

"Our study reveals that minimal interaction between only two tissue clocks is needed to maintain optimal functioning of tissues and to avoid their deterioration and aging," said Pura Muñoz-Cánoves, PhD, one of the authors of both studies. "Now, the next step is to identify the signaling factors involved in this interaction."

The researchers behind both studies hope that their research will guide other experts toward developing treatment plans and preventive measures for premature aging in the future. — Jackie Appel



Underwater UFOs

A RETIRED U.S. NAVY ADMIRAL BELIEVES that the government should look to the oceans to help solve a mystery in the skies. Rear Admiral Timothy Gallaudet, former Oceanographer of the U.S. Navy, recently published a paper arguing that unidentified anomalous phenomena (UAP, more commonly referred to as UFO) and unidentified submersible objects (USO) are linked, and should be studied further.

→ "Transmedium" UFOs Jeopardize U.S. Security

// In the paper, titled "Beneath the Surface: We May Learn More about UAP by Looking in the Ocean," Gallaudet writes that "transmedium" UAPs and USOs—defined as unidentified objects that appear to travel both in the atmosphere and in the water—"jeopardize U.S. maritime security. Gallaudet argues that the lack of knowledge about the undersea world poses hazards for submarines, such as collisions with other submarines—like the independent crashes of the submarines *USS San Francisco* and *USS Connecticut*, both of which were incidents that resulted in severe damage to the ships and one crew fatality—and undetected

underwater seamounts. Further study of this realm, he believes, could shed additional light on these UFO/UAP sightings.

→ **The Omaha Incident** // One incident to which Gallaudet points is a 2019 encounter between the Independence-class littoral combat ship *USS Omaha* and a so-called transmedium UAP. In the incident, the crew of the *Omaha* (sailing off the coast of San Diego) used their AN/KAX-2 electro-optical sensor to record a spherical UAP hovering just over the surface of the Pacific Ocean.

The object in the video seemingly moves, stops, and hovers a short distance above the surface of the ocean. Eventually, the object disappears, with sailors remarking that it made a splash as it entered the water. The video was leaked to UFO investigator Jeremy Corbell Lockyer, and was later verified as genuine by the Navy.

→ **Sightings in Puerto Rico and Elsewhere** // Gallaudet also references another sighting from 2013,

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spotted by U.S. Customs and Border Patrol personnel. The sighting—which took place near Aguadilla, Puerto Rico—was filmed using a similar imaging infrared camera. The video depicts another spherical object appearing to enter the water and then reemerge without losing any speed. The retired admiral writes, "Over three minutes, the object appears to fly at speeds between 40 and 120 miles per hour, enter and exit the Atlantic Ocean without any significant deceleration, reach a maximum underwater velocity of 95 miles per hour, and at one point split into two parts before entering the water again."

Other possible evidence cited by the admiral includes an incident in 2022, in which the NOAA underwater exploration ship *Okeanos Explorer* discovered an unusual series of holes on the North Atlantic seafloor at a depth of 1.6 miles. The centimeter-sized holes were in an unusually straight line, and scientists are apparently at a loss to explain their origin.

➔ **A Rare Moment of UAP Advocacy** // Gallaudet entered the U.S. Navy in 1989, and after his Navy career, he served for two years as acting administrator in charge of the National Oceanographic and Atmospheric Administration (NOAA). Today, he sits on the advisory board for Americans for Safe Aerospace, which describes itself as a "non-profit organization dedicated to aerospace safety and national security with a focus on unidentified anomalous phenomena (UAP)."

It's rare for a high-ranking U.S. military officer to directly address UAP issues, even in retirement. And the incidents Gallaudet calls attention to are unusual, to say the least. Barring flat-out hoaxing by military and civilian government personnel, the videos and photographic evidence are not easily explained. Whether this will result in greater research to the same extent as the UFO/UAP issue remains to be seen. —*Kyle Mizokami*

HOW TO FIX A DEAD WALL OUTLET



An outlet can lose power for any number of reasons. Here are a few of them—plus solutions.

A. The house wiring that serves the outlet has lost its continuity (a continuous electrical path).

SOLUTION: Call an electrician.

B. A splice inside the electrical box that serves the outlet has come loose.

SOLUTION: Redo the splice.

C. The wire that provides power to the outlet has come off the receptacle.

SOLUTION: Even if no damage is visible, assume the worst and replace the outlet. Also, cut and strip each wire and bend it into a clockwise-facing hook. Then tighten the hook under the terminal screw on the side of the outlet. If you've never done this before, check out the full version of this piece on popularmechanics.com.

D. The outlet receptacle is just worn out.

SOLUTION: Replace the outlet.

E. Sometimes the problem isn't with

the outlet but rather a nearby wall switch.

SOLUTION: Check that there is electrical continuity through the switch. If there isn't, replace the switch.

F. The circuit breaker tripped because something overloaded the circuit, or a wiring deficiency has resulted in a short. Thus, the entire circuit is dead.

SOLUTION: If the circuit breaker tripped because the electrical load on the circuit was too high, you may be able to correct this by simply removing electrical appliances or devices that caused the overload. Also, simple investigation may sometimes reveal that the cause was some wires that slipped out of a spliced bundle and shorted against the wall of a metal box. Cutting back damaged wire and neatening up the splice will solve the problem. However, in most cases, where heat damage is apparent or you see evidence that there is a possibility of larger electrical problems (such as finding gray-colored aluminum wiring, not copper, serving the outlet), your safest bet is to call a licensed electrician—not a handyman. —*Roy Berendsohn*

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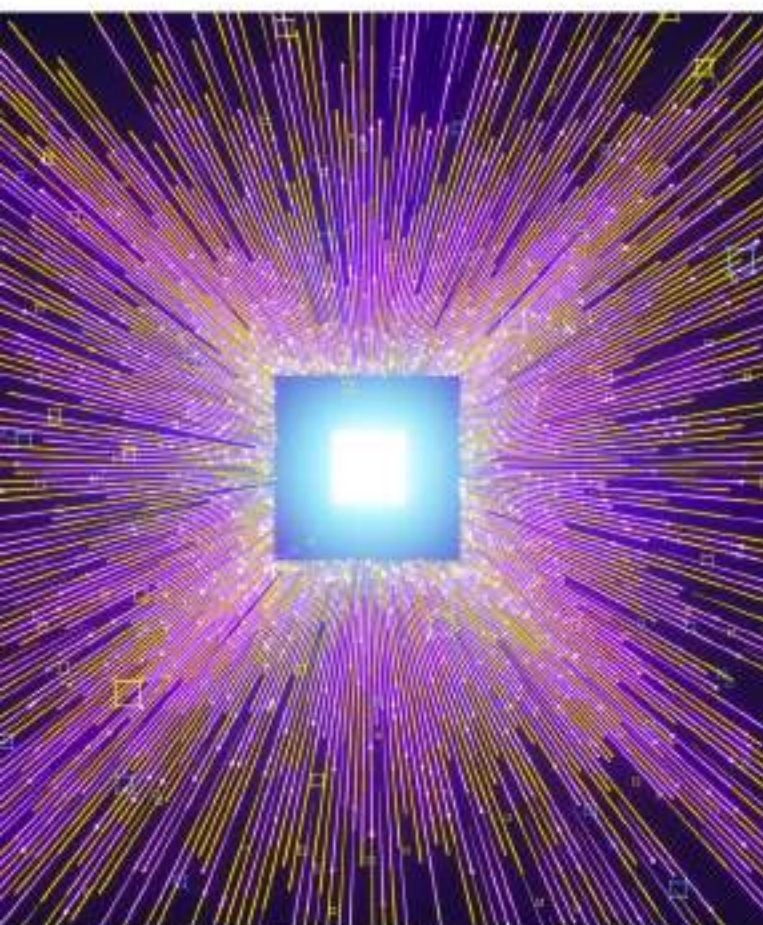
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YOUR COMPUTER WOULDN'T BE VERY useful without RAM, which is short for random access memory. These chips function as the temporary storage for an operating system, and their speed is of great importance, as they're constantly needing to access bits of memory to keep everything running smoothly. For more than two decades, the most advanced version of this technology—magnetoresistive RAM, or MRAM—has been the go-to tech for the kind of intense computing necessary in industrial, military, and space applications.



Now, a new breakthrough discovered by scientists at the Hebrew University of Jerusalem has illustrated how a mechanism in a laser beam can control the magnetic state in solids, which the scientists describe as a "paradigm shift" in our understanding of the behavior between light and magnetic materials. The results of the study were published earlier this year in the journal *Physical Review Research*.

"This discovery has far-reaching implications, particularly in the domain of data recording using light and nano-magnets," Amir Capua, PhD, head of the university's Spintronics lab and study coauthor, said in a press statement. "It hints at the potential realization of ultrafast and energy-efficient optically controlled MRAM and a seismic shift in information storage and processing across diverse sectors."

RAM works by using incredibly tiny electro-magnets that, once magnetized with voltage, can encode as "on" or "off"—1's and 0's in binary speak.

This breakthrough analyzes the often-overlooked magnetic properties of light, which led the research team to discover that rapidly oscillating light waves can control magnets—a huge boon in the field of memory and data storage. With their new mathematical equation, Capua and his team were able to describe the strength of this interaction, along with the "amplitude of the magnetic field of light, its frequency, and the energy absorption of the magnetic material," according to the press release.

Of course, the intersection of magnetism and light is old hat for the quantum realm, but the idea is rarely applied in the realm of spintronics—a portmanteau of "spin" and "electronics" that explores the relationship between an electron's spin and magnetism. This concept is what lies at the heart of MRAM, which uses an electron's spin to store information.

"We've arrived at a very elementary equation describing this interaction," Capua told the website Live Science. "It lets us completely reconsider optical magnetic recording and navigate our way to a dense, energy-efficient, cost-efficient optical magnetic storage device that doesn't even exist yet."

For now, that future is still a ways off. Today, MRAM is only beginning its ascendancy in the computing world, but this new discovery gives it a big boost as the memory chip of the future. —Darren Orf



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Henrietta Lacks

IT'S NOT SURPRISING THAT Henrietta Lacks—whose “immortal” HeLa cells were pivotal in developing treatments for diseases such as polio, HIV/AIDS, and COVID-19—is referred to as “the mother of modern medicine.” But Lacks’s legacy is complicated due to the ethical concerns surrounding the use of her special cells.

Lacks, who died of cancer at age 31 in 1951, was never aware that her cells led to significant medical advancements—or that they had been taken without her consent. And even now, her strange case raises questions about the morally dubious methods through which we achieved unquestionably positive breakthroughs in medicine.

➔ **The Immortal Life of Henrietta Lacks** // Though her cells live on in labs across the world, Henrietta Lacks remained largely unrecognized during her lifetime. It wasn’t until author Rebecca Skloot investigated the origins of the famous HeLa cells that Lacks’s story gained widespread attention with the bestselling 2010 book, *The Immortal Life of Henrietta Lacks*.

Lacks had been experiencing “abnormal pain and bleeding in her abdomen” when she visited The Johns Hopkins Hospital in Baltimore on February 1, 1951, where she was quickly diagnosed with cervical cancer. She received radium treatments and—without her consent—doctors extracted two cervical samples. Despite treatment, she passed away on October 4, 1951.

But unbeknownst to Lacks, or her family, the cervical samples revealed something extraordinary.

Lacks’s tumor cells were sent to the lab of Dr. George Otto Gey, a prominent cancer researcher. But unlike other samples he worked with, which died within a day or two, Lacks’s cells amazingly doubled in number every 20 to 24 hours.



Gey multiplied one cell into a cell line, which he named HeLa (after Lacks). The line became extremely popular and has been an integral part of nearly 11,000 patents. They were even used in the development of the polio and COVID-19 vaccines.

In February of 2010, Johns Hopkins addressed ethical concerns about the acquisition of the HeLa cells. “Sixty years ago,” the university’s statement reads, “there was no established practice of seeking permission to take tissue for scientific research purposes.”

But that’s not the full story.

➔ **The Evolution of Medical Ethics in America** // Ethical standards in medical science have dramatically evolved over the past century. In particular, the revelation of Nazi medical crimes during the Doctors’ Trials at Nuremberg shifted perspectives and led to the Nuremberg Code, which prioritized

voluntary consent in medical research.

But the U.S. didn't legally adopt the Nuremberg Code, nor did it immediately recognize the similarities between Nazi human experiments and its own practices.

In 1966, Dr. Henry K. Beecher published a paper in *The New England Journal of Medicine* titled "Ethics and Clinical Research." It's also known within medical circles today as "Beecher's Bombshell."

The paper criticized the use of unwitting patients in medical experiments, detailing 22 shocking cases that included soldiers given placebos for rheumatic fever based solely on their serial number, and patients being injected with live cancer cells without their informed consent.

The report rocked the medical world, as the tests it described were conducted not by Nazis, but by respected institutions, prestigious scientists, and the U.S. military. The paper strongly advocated for informed consent, and challenged the notion that ethical scrutiny could hinder scientific progress.

→ **How We Remember Henrietta Lacks** // The story of Henrietta Lacks often focuses on the medical breakthroughs that her immortal cells facilitated,

" THE PAPER STRONGLY ADVOCATED FOR INFORMED CONSENT, AND CHALLENGED THE NOTION THAT ETHICAL SCRUTINY COULD HINDER SCIENTIFIC PROGRESS.

rather than the scientific community's ethical missteps and her family's lack of compensation.

But Beecher has already argued against this idea, writing that an experiment "is ethical or not at its inception; it does not become ethical post hoc—ends do not justify means. There is no ethical distinction between ends and means."

We know now that those HeLa cells changed medicine forever, and Henrietta Lacks is immortalized in medical history. But we also know now that it should have been Lacks's choice whether she was immortalized at all. If only someone had thought to ask.—*Michael Natale*

MANIPULATION AND MEDICAL ETHICS



The taking of cervical samples wasn't the only medical procedure of dubious consent in Lacks's story. Once he saw how special the HeLa cells were, Gey wanted more than just two samples. But by the time he went to collect more cells, Lacks had died.

So, doctors sought consent from Lacks's husband, David "Day" Lacks, to perform an autopsy. "Though no law or code of ethics required doctors to ask permission before taking tissue from a living patient," Skloot wrote, "the law made it very clear that performing an autopsy or removing tissue from the dead without permission was illegal."

Initially, Day refused, but when doctors suggested that the autopsy could yield results that might benefit their children, he gave his permission. However, the promised test results were never provided to the Lacks family, despite being the reason consent was given for the autopsy in the first place.—*M.N.*



Whether We Live in a Simulation

IN THE 1999 FILM *THE MATRIX*, NEO DISCOVERS A truth to end all truths—the universe is a simulation. While this premise provides fantastic sci-fi fodder, the idea isn't quite as relegated to the fiction section as one might expect.

In fact, University of Portsmouth scientist Melvin Vopson, PhD, studies this exact thing—the possibility that the universe might indeed be a digital facsimile. And he claims to have evidence.

"In physics, there are laws that govern everything that happens in the universe, for example how objects move, how energy flows, and so on. Everything is based on the laws of physics," Vopson said back in 2022. "One of the most powerful laws is the second law of thermodynamics, which establishes that entropy—a measure of disorder in an isolated system—can only increase or stay the same, but it will never decrease."

Based on this famous law, Vopson expected that entropy in information systems—which he previously labeled a "fifth state of matter"—should similarly increase over time. But instead, it remains constant, or even decreases to a minimum value at equilibrium. This is in direct contrast to the second law of thermodynamics, which inspired

Vopson to adopt the Second Law of Information Dynamics (or Infodynamics).

Vopson argues that this law plays a role in atomic physics, cosmology, and biological systems. This last one is where Vopson makes a big claim: Contrary to the idea that mutations occur randomly, Vopson believes that they occur so that information entropy is minimized. To investigate this idea, Vopson analyzed the constantly mutating COVID-19, and his paper on that investigation shows a "unique correlation between the information and the dynamics of the genetic mutations."

What this all adds up to, in Vopson's estimation, is that the Second Law of Infodynamics could be used to prove that we live in a simulation.

All of these claims require significant further testing and verification before even being considered plausible, and there are plenty of research papers refuting our digital existence. It's possible that Vopson's Second Law of Infodynamics could lead to some interesting discoveries, but the question of the nature of our reality remains unanswered.—D.O. 

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SAVING THE SUGAR BUSH

A technological revolution has transformed the ancient tradition of sugar making—with big implications for local economies and ecosystems imperiled by climate change.

BY ASHLEY STIMPSON / PHOTOGRAPHY BY JUSTIN KANEPS



AARON WIGHTMAN WAS ALMOST BORN IN A SUGARHOUSE.

It was early April, and his parents were boiling maple sap in the Western New York shack where they produced syrup and other maple-flavored goods. "It was pretty rustic," Wightman says, "with just enough power for some lightbulbs." In other words, not the ideal place for his mother to go into labor.

Fortunately, the labor pains turned out to be a false alarm, and Wightman was born a few days later in the hospital—but it wasn't long before he was back in the sugarhouse. As a toddler, he crawled near the steamy wood-fired boilers his father tended over, sometimes all night. By the time he was 10 years old, Wightman was trudging through the woods, collecting hundreds of sap-filled buckets by hand.

Most of us, when we think about maple syrup, picture rosy-cheeked New Englanders dressed in buffalo plaid, tree trunks slung with galvanized buckets, and steam pouring from a rudimentary shack tinselled with icicles. As it turns out, our imaginations are a little outdated. These days, maple sugaring is less of a handcraft and more of a science, as new equipment has enabled producers to make more maple syrup—and money—



Sugar maker Aaron Wightman is working to understand how climate change could impact the color, flavor, and taste of maple syrup.



◀ Tangles of green hose stretch across Dan Weed's sugar bush, ferrying sap to his facility for processing. ▶ Angela Ferguson, the supervisor of the Onondaga Nation Farm outside Syracuse, New York, has blended technology and tradition to ensure the sap keeps flowing.

faster and easier, no all-nighters necessary.

Wightman has graduated from the family sugarhouse to the Cornell Maple Program, where he oversees 7,800 tapped trees across four miles of an experimental forest outside of Ithaca, New York. During sugaring season, the program's Arnot Maple Lab produces 400 gallons of syrup a day, a volume unthinkable just two decades ago, now made possible by state-of-the-art technology.

It may seem like niche science, but Wightman believes maple has a wide-reaching potential to satisfy America's insatiable sweet tooth and buoy local economies. What's more, a sugar bush—the term for a forest used to produce maple sap—is a part of a fully intact ecosystem, as opposed to other forms of sugar farming, which dismantle ecosystems. But he's far from the first person to realize these benefits. In fact, sugaring is one of the only Indigenous methods of agriculture still happening in America today.

In the last three decades, production of maple syrup in the United States has soared by 350 percent, according to Wightman, with sugar bushes popping up in Oregon, Iowa, and West Virginia. Producers in the Northeast, meanwhile, are trying new things: incorporating modern technology into Native foodways, for instance, or managing their sugar bushes for biodiversity. For his part, Wightman wants to keep the sap flowing as the climate changes.

To figure out how to do that, he and his colleagues have established the Cornell Maple Climate Network, an unprecedented regional effort to collect data that will help producers—and their trees—survive the largest existential threat they've ever faced.

AMERICAN MAPLE SYRUP ALMOST WENT extinct. In 1993, sugar makers in New York State, the second-largest producer in the U.S. behind Vermont, made only 180,000 gallons of syrup. A century earlier, in 1890, the number was more than 450,000 gallons. "It had almost faded away as an industry," Wightman says.

There were a few reasons for the decline. When the Second Industrial Revolution arrived in the early 20th century, agricultural production as a whole plummeted, and maple syrup—which was often a side hustle for dairy or beef farmers—was no exception. Meanwhile, consumers began choosing the cheaper, mass-produced sugar that was flooding the market. (The average American consumes about 7.5 tablespoons of added sugar each day, most of it derived from sugar cane and sugar beets.)

But by far the biggest challenge facing the declining industry was the herculean task of collecting, transporting, and boiling sap.

By the 1990s, factory farming and the convenience of ultra-processed ingredients had transformed much of our food systems—yet producing maple syrup remained stubbornly laborious. Harvesting maple sap required trudging through the woods, drilling a tap into and hanging a bucket onto hundreds if not thousands of trees, and then waiting patiently for the right climatic conditions to strike.

Sap begins to flow in late winter when daytime temperatures rise above freezing but fall back below it at night, a freeze-thaw cycle that creates pressure in the tree. After a good sap run, farmers had to rush to collect the sap, which can spoil if it becomes too warm.

Once the sap had been retrieved, the grunt work may have been over, but the long job of processing it was just beginning. When it



dribbles from the tree, sap is anywhere from 1 to 3 percent sugar. To make maple syrup, sap must be boiled down to a much sweeter 66 percent sugar, a process that took hours.

After the long boil, the syrup has to be filtered to remove so-called sugar sand (harmless bits of concentrated minerals that ruin the look of the finished product), a feat that sugar makers used to accomplish with cloth or paper filters, like the ones used in drip coffee makers. This final step was arduous and sticky—but necessary for a food famous for its golden translucence. “The technology just wasn’t there to process it efficiently,” Wightman says, noting that it takes about 40 gallons of sap to make one gallon of syrup. “You’d boil all night long and maybe you made some money at the end—but usually not. So until the 1990s, if you were tapping a couple thousand trees, that was considered huge.”

But that decade marked a turning point for the industry. Shiny, souped-up equipment suddenly made syrup-making at scale a viable enterprise. Powerful reverse-osmosis (RO) machines hit the market, which cut down significantly on production time by condensing the sugar in the sap. Meanwhile, commercial evaporators (also called boilers because they do just that—boil the remaining water from the sap) became supercharged, running on propane and fuel oil instead of endless cords of firewood. Even filtering got easier, as vacuum-powered presses that pushed the finished syrup through a series of ultrafine sieves became widely available.

“The machines in this room totally transformed industry,” Wightman says, looking around his Cornell laboratory. I’d come to visit the Arnot Maple Lab on a windy day in early March. The 4,200-square-foot space was opened in 2021 and replaced Cornell’s original sugarhouse, which lacked heat, reliable water, and a bathroom. The new lab, on the other hand, is full of instrument panels and gleaming steel, the new workhorses of a very old tradition.

Tucked away in their own room are the lab’s two reverse-osmosis machines, which, like

boilers, are designed to increase sugar content. These machines—nicknamed Maverick and Goose, after the *Top Gun* characters—are each composed of a control board atop two blue filters, fed by two cylindrical tanks the size of hot-water heaters and an interstate system of tubes entering and exiting from every direction. It’s a far cry from tin buckets and wood-fired stoves.

In other industries, RO machines are typically used to remove particulates from drinking water. Maple producers use them to remove water from particulates—in this case, sugar molecules. To accomplish this, the machines force sap through a porous membrane with holes large enough for water to pass through, but not the sugar. The smallest RO machines bring sugar levels from about 2 percent to 4, which may not sound like much but cuts boiling time in half. Wightman likes to run his RO machines as high as they will go, until the sap is about 20 percent sugar.

After a trip through the RO machine, the concentrated sap then flows to one of the lab’s two high-efficiency evaporators. In the Northeast, wood-fired evaporators used to be the site of communal gatherings, as all-night boils turned into a breakfast of hot dogs cooked in bubbling sap. Today, these rigs, which run on fuel oil and cost upwards of \$100,000 per unit, look a bit like chrome train engines, with covered boiling pans up front that recycle steam to the unit’s backside to preheat incoming sap.

While sugar makers still tap and untap trees by hand, plastic tubing has replaced buckets, and vacuum tubing systems mean sugarhouses no longer need to be built on low ground, where gravity could beckon the sap. When Wightman gives me a tour of Cornell’s sugar bush, where blue and green tubing weaves in and out of century-old

“IT’S NOT A BUSINESS VENTURE,” FERGUSON SAYS, “BUT A SPIRITUAL AND CULTURAL ONE.”

maples, he points to a vacuum sensor hung from a tree that resembles the controller for a remote-controlled car.

These sensors let staff know when there’s a leak somewhere in the miles of tubing—usually caused by a hungry squirrel or a fallen branch—and what line it’s in. While machines have replaced almost every aspect of maple production, “leak hunting is a continuous task,” Wightman says. “Ideally we have someone out looking every day.”

That means when he’s not in the lab or speaking to producers, Wightman still gets to spend some time in the woods. These are the hours he cherishes most.

PURE MAPLE SYRUP USED TO REQUIRE THREE INGREDIENTS:

“good sap, good wood, and good luck,” writes Michael Lange, anthropologist and Champlain College professor in his book *Meanings of Maple: An Ethnography of Sugaring*. These days, sugar makers might argue there’s a new item on that list: “good equipment.”

This new equipment has made sugar making less backbreaking,



Resilient sugar maples can handle the injuries caused by tapping. But climate change is another threat entirely.



according to Dan Weed, owner of Schoolyard Sugarbush, but not necessarily simpler. In today's industry, in addition to being a farmer, Weed says, "you have to be an expert plumber, an electrician, and an IT specialist all in one." (For all his technological savvy, Weed hasn't abandoned the basics. He gets his forecasts from the *Farmer's Almanac* and often uses the "Jones Rule of 86," a shortcut to estimate total gallons of sap required to produce one gallon of syrup: Divide 86 by the sugar content of sap (so for 2 percent sugar: $86 \div 2 = 43$ gallons of sap).

Weed's production facility is crowded with complicated-looking machinery, a setup Wightman admittedly envies. He had sent me to chat with Weed, who's the president of the New York State Maple Producers Association and an enthusiastic adopter of cutting-edge technology.

Weed, who resembles an off-duty Santa with a round nose and friendly blue eyes, led me on a tour of the various machines that the sap—which he collects from 47,000 taps spread across four counties in Southern New York—goes through once it reaches his sugarhouse.

The first stop is what appears to be, to my novice's eyes, a blue barrel lying on its side fed by a tangle of plastic tubes. This is the releaser, and it does just that. It releases the sap from Weed's vacuum system and pumps it back outside into one of his three 7,000-gallon storage tanks. When those tanks get full enough, the sap will be sent into Weed's RO machines, the "wicked expensive" ones he can monitor via cell phone while he's out making deliveries. "I can pull over and look at the sugar content, the pressure," he says, a bit of bemusement on his face even now.

When he started producing syrup in 1989, Weed used a toboggan to get the sap he collected from 240 taps back to his sugarhouse, a structure he built himself. Inside, he boiled sap all night on a wood-fired evaporator that processed about five gallons of syrup per hour. Today, his rig runs on natural gas and boils off 600 gallons in the same amount of time.

After the boiling process, Weed used to filter his syrup with wool cone



◀ Dan Weed, who has been producing maple since 1993, collects sap from 240 tapped maple trees on his property. ▶ The blue releasers in Weed's shop are designed to release sap from the pressurized tubes and into one of his 7,000-gallon storage tanks.

tic things, the old neck yoke, the old evaporator." For one weekend a year, the scene at Schoolyard Sugarbush looks more like it does on its syrup bottles than in real life.

IN LATE MARCH, ABOUT A WEEK AFTER WEED AND WIGHTMAN mark the end of their sugaring season, Angela Ferguson's is just beginning. As supervisor of the Onondaga Nation Farm outside of Syracuse, New York, Ferguson operates on a different scale—her goal is simply to feed her community—and a different schedule.

While Weed taps his maples during the first days of each new year, Ferguson's crew doesn't head out to the sugar bush until they hear the "big thunder," as she calls it, a distinctive thunderclap that erupts from an early spring storm. It is impossible to miss, she says: "It rolls across the whole sky, rattles the windows, wakes you up." That's when she knows the trees have woken up and are ready to give their sap.

The very first drops of sap that Ferguson collects are for the Nation's opening ceremony, an Onondaga tradition in which, as she explains, "we give thanks for the trees' gifts, for letting us have a relationship with them." During the ceremony, every member of the community takes a sip of the season's inaugural sap, even the babies.

The Onondaga's relationship with maple trees, which they regard as the leader of all the trees in the forest, is a very long one. Legend has it that sugar-making knowledge was born in the Haudenosaunee Confederacy (called the Six Nations by the English and the Iroquois Confederacy by the French) when an Iroquois chief left his tomahawk in a maple tree overnight, causing sap to leak from its bark. In the morning, his wife used the sap to boil meat for dinner, imbuing it with a new sweetness.

For centuries, Native people heralded the arrival of sap as much-needed nourishment in the depths of winter. To reduce the water content—what is today accomplished with an RO machine—they placed the sap in shallow troughs and allowed it to freeze overnight. Each morning, they removed a thick layer of ice, leaving more concentrated sap behind. Eventually, Native sugar makers boiled this concentrated sap down in large kettles—but rarely into syrup. Instead, they hardened it into soft cakes of sugar, which could be stored for years.

Ferguson sees her work as a continuation of this tradition. "In 2024, I'm still doing what my ancestors have done for thousands of years, but we're also adapting." She now uses plastic tubing, which festoons the Nation's sugar bush, as well as an industrial-sized evaporator, which Ferguson got in a trade with the nearby Seneca Nation for seven of the Onondaga's buffalo.

Ferguson founded Seven Buffalo Maple Company three years ago, but the name is a bit of a misnomer; the syrup is given away to community members. "It's not a business venture," she says, "but a spiritual and cultural one."

filters pinned to a clothesline, a process he describes with a smile and one word: "messy." Today, just as it does at Wightman's lab, the syrup in his sugarhouse is pushed through an accordion-shaped filter press until it's nearly translucent.

Here in the Empire state, maple is an agritourism darling, the star of late-winter festivals everywhere. During my visit to New York, Weed was getting ready for New York State Maple Weekend, a sugarhouse crawl across the state, when hundreds of visitors cram into his business to learn how syrup gets from Weed's woods to their breakfast table.

Weed says most people aren't interested in his RO machine, but rather come to indulge in some regional nostalgia. He admits to some artifice. "We try to pull out the authen-



◀ Pressurized hoses that stretch across New York's sugar bushes have removed the need to build maple sheds in low-lying areas. ▶ High-efficiency evaporators in Wightman's lab have replaced the old-fashioned boilers of yore.



Lots of people on the reservation had been tapping trees in their backyards for years, but the Nation's sugaring efforts were individual and scattershot. Ferguson wanted to reconnect with communal and ancestral ways, while also producing enough to feed everyone—with a little left over to save. The tubing and evaporator allow her to do this with more ease and efficiency, but she's not interested in optimization for optimization's sake. For instance, she has no interest in installing a vacuum system to pull sap from the 600 or so maples in her sugar bush. "I want whatever naturally flows to be given to us," she explains, "I don't want to be extractive by pulling it out."

In April, when the sap does stop flowing, the Onondaga celebrate with a closing ceremony. The 2024 sugaring season will be shorter than usual, but for Ferguson, it's about time spent, not gallons made. "We have these gifts from nature, and we are supposed to come and receive them, so they don't ever leave us."

Ferguson isn't the only sugar maker concerned about doing things the right way to ensure the future of the crop. Wightman says that even five years ago, when he brought up the threat of climate change to a group of producers, "I used to get a lot of folded arms, a lot of people arguing with me." That is no longer the case, he says. A recent survey found that 89 percent of sugar makers have already experienced the negative effects of climate change. New England is one of the fastest-warming regions in the U.S., a trend that had forced maple producers to revise the timetables they have followed for centuries.

"Today, our season is over before we would have even tapped," says Wightman, who used to spend April next to his dad in the family's sugaring house. These days, the trees in Cornell's forest begin budding (the checkered flag of the sugaring world) in late March. His experience is not unique. Most producers say their seasons are starting and ending much earlier than they used to, and multiple peer-reviewed studies have predicted that tapping seasons will grow shorter by the end of the century.

Climate change also brings with it more severe weather, like high winds that bring down trees that sever tubing lines, as well as

winter heat waves that clog lines prematurely. Warmer temperatures will also affect sap chemistry—and possibly the taste of syrup—and invite invasive species and new plant diseases into the woods.

That's why Wightman and Adam Wild, his Cornell counterpart who heads up the university's Uihlein Maple Research Forest in Lake Placid, have launched the Cornell Maple Climate Network, setting up monitoring stations across the Northeast, Midwest, and Canada to collect valuable data about the relationship between the *Acer saccharum* (sugar maple) and its environment.

"We want to understand every factor that influences production," Wightman explains when he shows me the solar-powered monitoring station in the woods outside the lab, where a tapped maple has been injected with temperature and pressure probes. Meanwhile, sensors take in a smorgasbord of data: air and soil temperature, atmospheric pressure, precipitation, among others. It's a simple and accessible setup. Wightman says he and Wild used off-the-shelf, Internet of Things technology to assemble the monitoring stations.

For now, the project aims to gather baseline knowledge of how climate affects sap flow, sugar content, and overall yield, data that will inform strategies for sugar makers contending with climate change. "For example, if we learn that there are soil-moisture thresholds during the growing season that correlate to sugar content, we can start thinking about water-management strategies in the sugar bush," Wightman says. "If the data shows a strong relationship between soil temperature and sap yield, that could be used in developing sugar bush management prescriptions around evergreen species that shade the forest floor."

It may come as a surprise that, despite humans' long and delicious relationship with maple trees, scientists still don't completely understand what makes a maple tree's sap flow. "Tree physiology is something we're still working on," says Wightman. By amassing vast tomes of data from around the maple-growing region, he and Wild hope to unravel that mystery so they can provide guidance to producers about where and when—and eventually *what*—to tap in a climate-changed world.

On that last point, while maple trees are known for their hardiness—Wightman says they can "heal their own wounds" after the annual tapping season—that resilience may

not translate in a warming world plagued by pests and pathogens. Both Wightman and Wild are raising experimental sugar bushes of birch and beech trees, sap-producing species that might better tolerate a volatile future.

There have always been financial incentives for protecting the long-term health of the sugar bush ecosystem—most sugar maples aren't tap-worthy until they're about 40 years old—but there are countless other benefits, too. While sweeteners like sugarcane and sugar beets require vast tracts of cleared land, chemical fertilizers, and a staggering amount of water, sugar bushes sequester carbon, filter groundwater, and support other crops besides maple. Wightman grows currants, pawpaw, and elderberry in the lab's sugar bush.

And the family farms these forests stand on often serve as an intact ecosystem where other plants and animals can still thrive. Wightman and the team at Cornell recently teamed up with Audubon New York to launch the Bird-Friendly Maple certification program, which encourages producers to manage their sugar bushes to optimize breeding and foraging opportunities for forest birds, a class of birds in steep decline.

The ecosystem's resilience paired with the technological advances that have supercharged maple production have so far shielded sugar makers from the worst of the climate-induced pain. But that won't always be the case.



THE LAST FEW SUGARING SEASONS HAVE BEEN UNPREDICTABLE for producers in New England, a reminder that all the modern equipment in the world is no match for the whims of nature.

That's why Weed, whose sugarhouse is decked out in all the latest maple gadgets, believes the producers should continually return to their roots—literally. "We need to put our hands in the dirt," he says. By that he means sugar makers must take good care of their most important resource—their forest.

"People tend to think that pristine means unmanaged. But that's not true," Weed argues. Sugar makers can enhance their woods' resilience to natural disturbances by managing for invasive species, removing diseased trees, and cultivating trees other than maples. "It takes a lot of time and money to accomplish, but those woods will be so much better off in 20 years," he says.

In the meantime, Wightman is using the woods in his charge to find ways to make life easier for producers like Weed, both now and in the future. This is the kind of work that Wightman, who calls himself "an idea guy," came to Cornell to take on. "I wanted to do something big here," he says, and a day at the lab—with its *Top Gun* equipment and ambitious experiments—is proof he's doing just that.

Despite those bells and whistles, Wightman admits it's the rustic old sugarhouse in Western New York—the one he was almost born in—where he most feels the magic of sugar making, its long history, and promising future.

"When I boil there, and step outside and see the stars, I think that this is the exact same experience my grandfather had, and his father and his father. I feel really connected," he says. "I love that intergenerational feeling, that feeling of carrying-on of tradition."

It's a tradition he's working diligently to protect. ■

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INDISPENSABLE LESSONS FROM A POP MECH LEGEND

A stylized illustration of Roy Berendsohn, a bald man with a friendly expression, wearing a dark button-down work shirt with his arms crossed. The background behind him is a light blue, textured wash.

by
ROY BERENDSOHN

illustrations by
JOEL KIMMEL

photography by
TREVOR RAAB

► Test Editor Roy Berendsohn, who is retiring after a 35-year career at *Popular Mechanics*, is one of the world's foremost experts in DIY and living well. Here's his parting wisdom on essential jobsite skills and the life lessons he's learned along the way—as straight and true as anything he's ever built for us.

W

ith people moving around so much these days, it's perfectly natural to wonder how an editor can just come along and stick like a barnacle to the hull of *Popular Mechanics*, lasting for 35 years. People laugh when I tell them how the two of us became acquainted. It happened this way. I took my résumé, cover letter, some clippings, and

photos from my work as a newspaper reporter-photographer and bundled the whole mess together, addressed it to this magazine, and put it in the mailbox. Then I dutifully raised the red flag on the box so the postal carrier would be sure to stop. I went inside and cracked open the *New York Times*. By then, my journalism professor had passed away, but you might say I could still hear his voice exhorting his students to always read the obituaries. If anything, read them first. "You always want to find out who just died," he said. My professor was Arnold Brackman (he has a Wikipedia page), and he was tremendously wise in many things, but especially journalism. So, I turned to the obits and learned that the editor in chief of *Popular Mechanics*, John Linkletter, had just died. Although I never knew him, I was told that he was adored by his staff, a mentor to many, and emblematic of his generation—a WWII Navy pilot serving off of carriers and a sturdy son of the Midwest. But there he was, gone.

Then opening *Popular Mechanics* to its masthead page, I saw that executive editor Joe Oldham was next in line. Now you may find this pathetically innocent, too young to know better, or just plain dumb, but I assumed that Joe would be promoted to editor in chief. So, I went out to the mailbox, fetched my package, and retyped a new cover letter, addressed to Joe Oldham, Editor in Chief, *Popular Mechanics*. I redid the label and slipped the package back into the mailbox. Minutes later, along came the U.S. Postal Service.

I learned later from Joe's assistant, Barbara Novak, that the envelope with my cover letter and résumé was the first piece of mail he received, addressed to him, on his first day in the front office. Joe was famous as a street racer in New York and for his automotive writing. He wrote on my cover letter, "call him in," and sent it down the hall to department head Steve Willson, an incredibly skilled carpenter and journalist. Steve saw something in me, a know-nothing greenhorn. Perhaps it was my sincere desire to learn. With his own reputation on the line, he called me in. What followed was an interview and a written exam on home construction, plan reading, woodworking, and other basics. I passed that and sat for the second test, in which Steve grilled me on various topics not covered in the written exam. I cleared those hurdles and had a meeting with Joe. Much to my amazement, Steve recommended me and Joe hired me. I owe my 35 years here to these two hardworking men.

MY FIRST FULL
ISSUE BACK IN
AUGUST 1989



I've learned a lot from the various people I've worked with over the last 35 years. Here's some of what they taught me.

BUILDING CODES

I have three observations about building codes. First, I've heard building codes described as the set of rules that will permit you to build the worst house that you can still get away with. Having seen a lot of houses in my time, I can vouch that there's some truth in that morbid humor. This leads to my second observation, that you're not going to go wrong exceeding what the code permits. You don't have to go crazy (use four nails where the code calls for two), but overshooting the code (at least slightly) is rarely a bad thing. It comes down to



this: Building codes are the minimum acceptable standard. Go up from there.

Finally, try your best to understand the code that applies to where you are. When it's not clear, ask knowledgeable people (code officials, recognized trade experts), drop in on chat rooms, do your homework by reading commentary on building codes. Codes are dull reading and can be maddeningly difficult to understand. That's no excuse for ignoring them.

TIP One of the best code references I know continues to be *Code Check* by Redwood Kardon. Students aspiring to be electricians should read anything produced by electrician, author, and code authority Michael Holt; also, his videos are incredibly good. On old house electrical wiring, the gold standard continues to be the book written by electrician

David Shapiro, *Old Electrical Wiring: Evaluating, Repairing and Upgrading Dated Systems*. For plumbing, the book *The Ultimate Guide to Plumbing* by master plumber Merle Henkenius is peerless in its thoroughness.

MARK PRECISELY

To build correctly, you need to indicate cut lines and hole locations with accuracy suitable to the work. Here's how these common marking tools are used:

Lumber crayon, chalk ▶ Used to mark rough or fast cuts in framing lumber or for marking rough-sawn hardwood to prepare it for processing.

Carpenter's pencil ▶ Used to make quick-but-accurate marks on framing lumber.

Sharp No. 2 or HB pencil ▶ Used to mark wood trim or to darken a scribe



line made with a knife.

Marking knife ▶ Used to mark hardwood and softwood in building furniture and in making millwork, such as stairs and windows.

Awl ▶ Used to mark hole locations in wood and metal and to scribe lines in aluminum, brass, copper, and steel.

TIP At the start of a big carpentry job, I sharpen up to six carpentry pencils. When one gets dull or its tip breaks, I swap it out immediately.



BE PRECISE, UP TO A POINT

Precision is good. But like anything good, you can have too much of it. And too much precision wastes your time and can unnecessarily drive up the cost of making something.

A house isn't built with the precision that a piece of fine furniture is. And as good as a piece of furniture is, it's nothing compared to the tolerances you find in a machine shop. So, keep your perspective when it comes to precision. Learn to measure and mark with a precision that is suitable to the job.

TIP When using a tape measure, pull the tape taught and turn the rule's face against the workpiece. Next, place your pencil against the rule's edge and mark. (Thank you, Tom Klenck.)

BE SHARP, NOT CRAZY

Sharpness is relative. If all I need to do is remove the saw marks from a piece of lumber, a reasonably sharp hand plane is called for. That's all. If I am joining two pieces of wood together to form a glued assembly, then a perfectly sharp hand plane is needed. I sharpen a tool to perfection when perfection is called for. If perfection isn't called for, ordinary sharpness will do.

TIP When sharpening a hand plane, don't forget to hone the cap iron. This is the curved piece of steel that is screwed to the plane iron and deflects wood shavings. It should be nearly as sharp as the plane iron itself. Its edge has to be flat, smooth, and straight such that when you lock it down on the plane iron, no wood shaving can work its way under it.

AVOID BREAKOUT

Breakout (splintered edges left by a drill bit, saw blade, or router blade) is the bane of woodworkers and metal workers, yet it's fairly easy to avoid using several easily applied methods.



BREAKOUT TIPS

1 // Use a backup block. If an exit hole through a piece of wood has to be as clean as the entry hole, put a sacrificial block of scrap wood behind where you are drilling so that any breakout occurs in the scrap block, not the workpiece. (Thank you, Joe Truini.)

2 // Pay attention to bit and blade sharpness and cleanliness. A sharp bit or blade cuts more cleanly than a dull one. A clean bit or blade cuts more cleanly than one fouled with residue.

3 // Slow down: Machinists live by speed and feed when machining metal. The same holds for you working wood. You can have the right blade or bit, but if you're feeding the wood into the table saw blade too quickly, as one example, you're not going to get a high-quality cut. You're also decreasing your safety.

4 // Use an appropriate blade or bit for the job. Blades for circular saws, jig saws, and band saws all come in widely varying tooth geometry. Likewise, there is no such thing as a single drill bit for every material and every job. If you want to increase the cleanliness of your work, do your homework. Read manufacturer's data. Look up blade profile charts. This stuff isn't fun to read. Still, you need to know it.

BE A BETTER AMATEUR WELDER

The best welder I know is my nephew, Andrew Peterson. He's passionate about his trade and has a long list of welding certifications. As he's often said to me, the more [metal] you burn, the more you learn. That is, the more welding you do, the better you get at it. Welding isn't easy to do well, so before your next welding project, keep these tips in mind.

WELDING POINTERS

1 // Don't look at the arc, look at the weld puddle. The arc is blinding, even with a welding mask on. Besides, it's not where the action is. The action is where the rod or wire melts off and forms a puddle. See the next tip.

2 // Adjust the variables. You'll weld poorly if the puddle is messy, shaped like an amoeba, and has metal flying



in all directions. To neaten up the puddle, adjust your welding parameters. Alter your wire-feed speed, electrode stick-out, speed of travel over the work surface, and amperage setting (to name a few things). You should see a neatly shaped weld puddle without a lot of splatter.

3 // I don't weld every day. Before I weld anything, I practice on scrap metal.

4 // Read. I'm constantly reading about welding. There's no shortage of good manufacturer's data on this topic, and there are many low-cost manuals available from trade associations, equipment manufacturers, and the manufacturers of wire and stick electrodes.

CONCRETE IS NOT SOUP

When it comes to concrete, less water is more. For example, Sakrete reports that an 80-pound bag of High-Strength Concrete Mix requires only 3.5 quarts of water to achieve its full hardness of 4,000 psi. There are several reasons for this precise amount, but the most crucial is the water-cement ratio. Concrete cures, it doesn't dry. That is, it becomes hard through chemical reaction. The correct water-cement ratio drives this process. But, usually, people add too much water. I've seen some use twice the amount of water specified. They pour a soupy mess into the form and end up with weak concrete.

TIP In hot weather, try to work early in the morning. Aside from being easier on you, cooler temperatures slow the concrete's curing. Also consider using a curing agent applied to the top of the concrete as soon as the material's surface sheen disappears. The agent holds water in the slab, slowing the curing. The result is stronger, tougher, and more durable concrete.





I consider the life lessons that I've learned at *Popular Mechanics* to be more important than the mechanical knowledge I've acquired. Both are important, but these lessons are the ones that I'll take with me right to the end.

GET ALONG WITH PEOPLE

It's not optional; it's easier than you think, and there's no excuse not to. I spent 30 of my 35 years working in New York City, a place known for its diversity. If we could find common ground and form lasting friendships, despite our differences, so can you.

TAKE CRITICISM WELL

I've faced some intense criticism in my 35 years as a staff editor. I've come close to being fired twice. It can be discouraging. As fierce as that storm has been, it made me tougher and a better editor. Would I have preferred a gentler or more humane delivery? Yes. And I'll pause here to say that where criticism crosses a line and becomes abuse is sometimes clear but sometimes is not so clear. Regardless, weathering it well is important. Example: One of my bosses was so withering in a critique of my work, about all I can say is that it was some of the harshest criticism I've ever faced—from anybody. As it turns out, he was also the best boss I ever had. And I've had many.

TAKE A LONG VIEW

Whether you get fired or not, find financial success or not, find your work satisfying or not, take the long view. Try your hardest every day to do the best you can—on and off the job. Look at whatever you accomplish on any given day as placing another brick in a long, sturdy wall that you're building. If nothing else, you can look back at that wall someday and know in your heart that you tried your best.

STAY HUMBLE

I've worked with incredibly talented people, and I've always been inspired that they were so thoroughly self-effacing. They were quick to give credit to mentors, business partners, teachers, friends, parents, grandparents, and many others.

WORK HARD

I like this piece of biblical direction: Whatever your hand finds to do, do it with all your might (Ecclesiastes 9:10). For society to flourish, people have to work hard. I'm not saying your hard work will always be rewarding or well-regarded. I'm saying it's necessary for the good of society.

RELAX WELL

Hard work is good. So is rest. You need both.

FIND A MENTOR

If you can find a mentor, consider yourself blessed. One of the life-changing aspects of my work here was that I had many good mentors helping and guiding me in different ways (colleague Tom Klenck; department head Steve Willson; contributors George Retseck, Joe

Truini, Merle Henkenius, Rosario Capotosto, and Neal Barrett; editors in chief James Meigs and Ryan D'Agostino also come to mind). I paid attention to what they said and did my best to apply it. One of our longest-serving and most valuable contributing editors was Norman Becker, a licensed mechanical engineer. Norman taught me so much that no amount of thanks could ever repay his kindness and patience. Which leads me to this last and important point. When a mentor calls for specific action, take it. When Norman told me that I needed to study something, I bought a textbook on the subject (physics, for example), and I read every page of it.

IT'S ABOUT YOU

My last thought about 35 years at *Popular Mechanics* is that my work here hasn't been about me. It's never been about me or for me. It's about you, the reader. Thank you for finding enough value in my work that you've read what I've written. It's been one of the great honors of my life to serve this readership for so long, and that includes you. 



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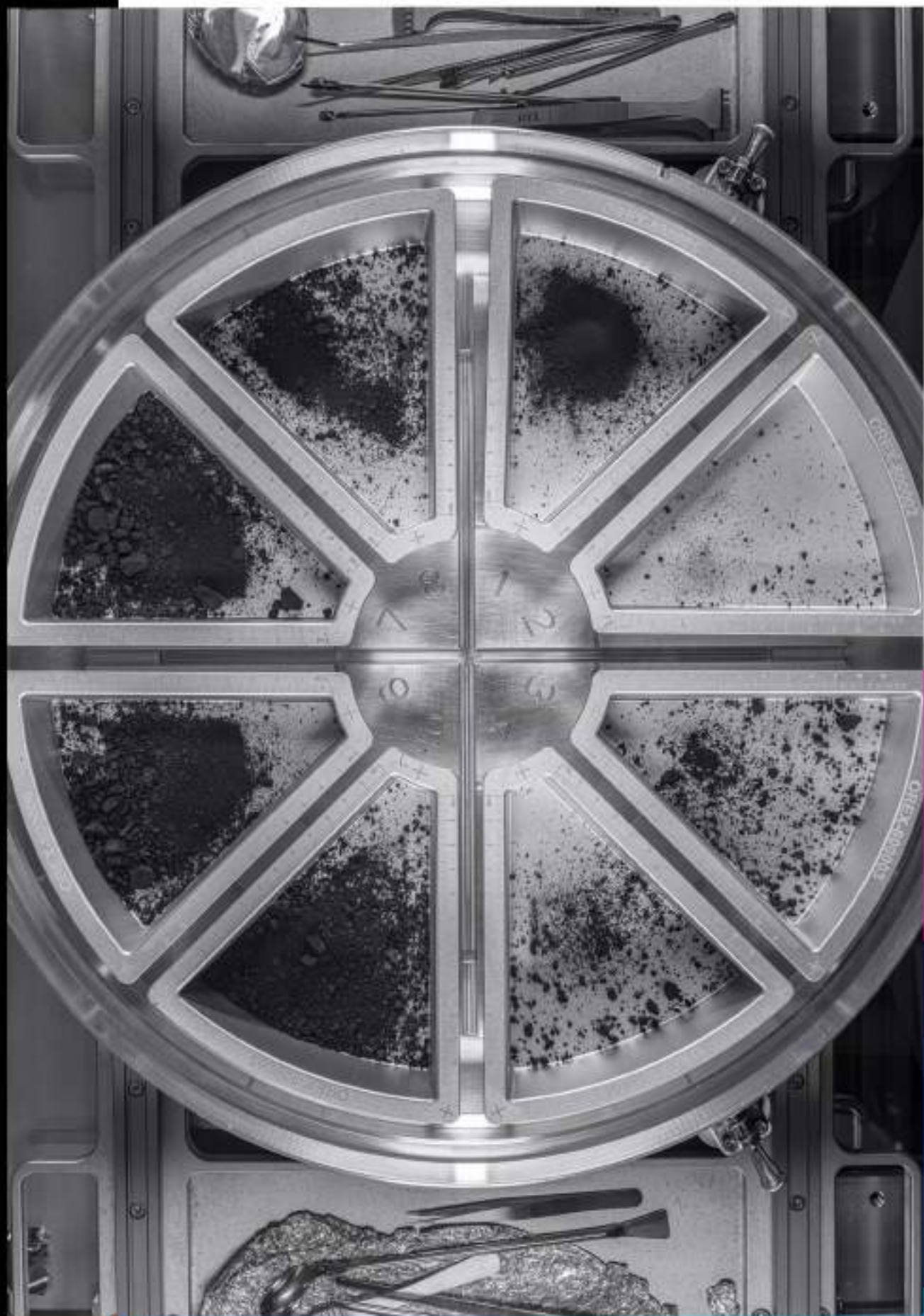
HOWIE
MANDEL

GOING DOWN TO HIT THE ROCK



HOW
NASA DEFIED
INCREDIBLE
ODDS TO GET
ITS ASTEROID-
HUNTING
OSIRIS-REX
MISSION OFF
THE GROUND
AND IN THE
PROCESS
UPENDED
WHAT WE
KNOW ABOUT
OUR SOLAR
SYSTEM.

BY ROBIN GEORGE ANDREWS





DANTE LAURETTA SAT IN THE BACKSEAT OF A HELICOPTER HOVERING HIGH ABOVE A REMOTE PATCH OF UTAH DESERT, WAITING FOR A SMALL, TWINKLING SPECK IN THE SKY TO PLUNGE TOWARD EARTH.

If you didn't know better, you might think what was beginning to burn through the skies above the American southwest in the early hours of September 24, 2023, was a shooting star. But it wasn't a shooting star. Or a meteor. It was a dishwasher-size capsule filled with bits of ancient asteroid—priceless matter from the dawn of the solar system. In other words, it was a treasure chest moving at 27,000 miles per hour and sizzling at a temperature half that of the sun's surface.

That small streak of light represented the end of a NASA-led interplanetary mission suffused with peril. Lauretta and his colleagues had spent nearly 20 years building a spacecraft designed to collect mate-

rial from an asteroid and return to Earth. From these precious grains, they hoped to gain insight about the formation of the solar system, of Earth, and maybe even of life itself.

What the capsule had to do now, completely autonomously, was simple: stay in one piece as it reentered the atmosphere, open its parachutes, and softly touch down on an Air Force bombing range without detonating any unexploded ordnance nearby.

By 8:44 a.m., the capsule was 102,300 feet above the ground, and its drogue parachute—the canopy meant to stabilize its plunge—should have opened by now. But no one could see it. Throngs of scientists and engineers who had worked on the spacecraft, spread out across mission control rooms in Arizona and Colorado, were now deathly quiet.

It looked like something had gone wrong. And all Lauretta,

the mission's leader, could do was watch, and hope, that his life's obsession wasn't about to be scattered across the desert. He wasn't even supposed to oversee the mission.

IN 2004, LAURETTA WAS WORKING AS AN assistant professor at the Lunar and Planetary Lab in Tucson, Arizona. One crisp day in February, representatives from Lockheed Martin approached his advisor, Michael Drake, who was then the Lab's director, and asked, rather matter-of-factly, whether he wanted to steal parts of an asteroid and bring it back to Earth.

The idea appealed to Drake, a straight-talking planetary scientist who had long endeavored to find out how worlds like Earth took shape. Drake asked the then 33-year-old Lauretta, who had joined the lab three years earlier, to be his deputy. It was an easy decision, Lauretta recalls: "People wanted to be part of the adventure."

Lauretta had never planned to become a space scientist. While he triple-majored in physics, math, and Japanese as an undergrad at the University of Arizona, he had spent summers taking jobs as a short-order breakfast cook and hopscotching across the Sierra Nevada mountains in a beat-up Volkswagen van. As he recalls in his recently published memoir, *The Asteroid Hunter*, he was adrift. It wasn't until he opened a copy of *The Daily Wildcat*, the university's student newspaper, that inspiration struck. Inside one of the spreads, a full-page ad in a blocky font read: WORK FOR NASA.

He knew that the agency was asking big, complex questions—questions that he, too, had often pondered. He applied and was offered a placement as an intern on a NASA Undergraduate Research Program at the University of Arizona, and started working on answers to some big questions: Where did we come from? How did life on Earth evolve? These questions had preoccupied him throughout grad school, and long after he earned his PhD in 1997. The answers, Lauretta believed, could be found within asteroids and comets—debris left over from the solar system's violent formation. All his efforts had been pointedly aimed at cracking those cases of cosmic intrigue.

Now, it seemed, he would finally get that chance as Drake's second-in-command. So, shortly after their initial rendezvous with Lockheed Martin, Drake and Lauretta joined the aerospace firm's director Steve Price for drinks at the Arizona Inn, a boutique hotel just off campus. Over cocktails, they sketched out their plan for the mission on a napkin.

They would have to build a spacecraft unlike any other and then somehow train it to autonomously collide with an asteroid, before returning its precious cargo to Earth for scientists to study. It would have to complete these tasks without missing a single step on

its Rube Goldberg-like mission.



FIRST, THE TEAM HAD TO SELECT AN asteroid to target.

Of the roughly 1.37 million known asteroids in our solar system, the team selected Benu, a carbon-rich pile of boulders in a prime location. While most asteroids orbit along an invisible gravitational freeway between Mars and Jupiter known as the Main Asteroid Belt, Benu lies along an orbital plane roughly 105 million miles from the sun. (Earth's average orbital distance from the sun is 93 million miles; Mars orbits along a path approximately 142 million miles from our star.) This meant Benu would be relatively easy to reach and, therefore, easier to study. What's more, Benu stood a small but nonzero chance of impacting Earth in the 22nd century, so it would be useful to spy on.

Broadly speaking, asteroids are important to study for two reasons. The first is a matter of planetary defense: They can impact, and have impacted, Earth. Asteroids the size of cars often do no damage; those the size of football stadiums—Benu is three football stadiums wide—can wipe out entire cities. Those the size of cities can cause mass-extinction events by triggering environmental and climatic pandemonium—just ask the dinosaurs. Knowing where these roving asteroids are, where they are headed, and how we can deflect or destroy them if required, is of paramount importance to our continued survival.

Additionally, some asteroids contain material that existed before the sun's thermonuclear fires were first lit, meaning they preserve a record of matter that crystallized or synthesized before the solar system came to be. An asteroid, then, is "a time capsule," says Richard Binzel, an astronomer and asteroid expert at the Massachusetts Institute of Technology, who joined the mission in 2004. "It's a way of going back in time, and asking: What were the original ingredients that made the Earth, and made us? What was the secret recipe?"

Water, for example, is one of those ingredients. While it can be found throughout the solar system, not all water is the same. The water we drink, the liquid in our oceans, the cascading rivers—did it all originally come from within our planet or was it delivered to Earth by comets and asteroids? And then there's organic matter—carbon-rich chemicals, ranging from small and simple amino acids to remarkably byzantine compounds. Organic matter isn't synonymous with life, but life as we know it both uses and forges it. Early observations of Benu revealed it to be dark as coal, which suggested it was rich in organic matter. Studying the asteroid could help researchers understand whether similar objects may have

4 Benu formed roughly 4.5 million years ago alongside our solar system. Its age and composition—rich in organic molecules—make it a prime target for study.



brought these ancient ingredients to Earth billions of years ago.

Researchers do study space rocks that have fallen to Earth and have gained insight into a collision's aftermath from these samples. For example, the remnant shards of the dinosaur-slaughtering Chicxulub meteor and the crustal rocks it flash-melted—both carefully extracted from the Gulf of Mexico—paint a terrifying picture. But there are limitations to these investigations.

While smaller meteorites that land in people's backyards can contain minerals, organic matter, and water that may be a match to Earth's own, "everything that falls to Earth's surface is contaminated or altered in some way," explains Jessica Barnes, PhD, a cosmochemist at the University of Arizona. The only way to truly answer any of these questions—particularly the cosmochemical ones—is to go into space, snatch a pristine and uncontaminated piece of asteroid, and bring it back home.

Bennu, it seemed, was the perfect target. Drake, Lauretta, and the rest of the team were going to send a spaceship to sample it.

▲
Dante Lauretta (left) joined the OSIRIS-REx mission in 2004. Daniella DellaGiustina (right) is overseeing the next phase of the mission.



HIS WOULD NOT BE THE FIRST spacecraft to attempt to collect matter from an asteroid. JAXA, the Japan Aerospace Exploration Agency, had already done so. Their first attempt,

when Hayabusa 1 sampled the asteroid Itokawa in 2005, was riddled with glitches, and only managed to bring home a mere 1,500 microscopic grains—a minuscule haul. The Japanese space agency's second heist was already in the planning stages. Hayabusa 2 would launch in 2014 and was scheduled to blast a copper cannonball through the asteroid Ryugu—an organics- and water-rich asteroid, like Bennu. If successful, the spacecraft would return a teaspoon's worth of asteroid back to Earth for study.

Drake and his colleagues hoped to grab at least 10 times as much material—perhaps 100 times as much—from Bennu. To do that, they needed to design an impressive suite of instruments specifically for this mission, a bit like making a very specific key to fit a one-of-a-kind lock.

Designing a spacecraft is a constant battle between scientists and engineers, explains Jason Dworkin, the senior scientist for astrobiology at NASA's Goddard Space Flight Center in Greenbelt, Maryland. As one of his colleagues likes to say: "If engineers designed missions, they'd launch a bowling ball into space. If scientists designed missions, they would have a battleship full of instruments that's too heavy to get off the pad." The key, explains Dworkin, who joined the mission in 2004, is finding compromise. Once the design was finalized, the team could submit it to NASA for review.

Finally, in May 2011, after three submission attempts by Drake's team, NASA selected OSIRIS-REx—the Origins, Spectral Interpretation, Resource Identification, and Security—Regolith Explorer—for flight. The mission's name, devised by Lauretta, felt apt. Osiris is the Egyptian god of agriculture and the underworld—a representative of life and death, just like asteroids often are to us. Now, Lockheed Martin, under the scientific supervision of the University of Arizona, could finally piece together a cutting-edge pickpocket.

While the team knew that many challenges lay on the path ahead, it still came as a shock when the first arrived in the fall of 2011, just four months after OSIRIS-REx was approved for flight. Drake, who had been diagnosed with liver cancer, had seen his health decline in recent months. And, on September 21, he passed away in Tucson.

Drake's death devastated the team. "I didn't expect to be the [principal investigator]—ever," Lauretta says. But suddenly, he was in charge—the shepherd not just of a scientific mission, but of the ambitious dreams of his mentor. The team would honor Drake by including a dedicated plaque on both the spacecraft and its launch vehicle.



THE NEWLY MINTED LEADER AND his colleagues spent the next few years building the spacecraft. By this time, Daniella DellaGiustina rejoined the team. She had been involved with the mission since around 2006, back when she was an undergraduate at the University of Arizona, with Lauretta as her mentor. Although she left to complete a master's degree in computational physics, the early OSIRIS-REx team member returned in 2014 as an image processing scientist and would be responsible for developing the images that the spacecraft took of Bennu.

OSIRIS-REx would be adorned with a series of cameras, each able to examine the asteroid's surface in a unique way. A cutting-edge altimeter would provide it with a radar-like ability to detect its distance from the target—but instead of radio

waves, this instrument would use lasers. Three spectrometers on the spacecraft would use electromagnetic radiation coming from the asteroid to map out its mineral makeup.

But, unquestionably, chief among its Swiss Army Knife-like gadget suite was TAGSAM: the Touch-And-Go Sample Acquisition Mechanism. OSIRIS-REx would find its way to Bennu, pilot itself down to the surface, and use an extended arm to prod the rubbly environs. A cylinder of compressed gas would then be fired into the asteroid, forcing matter up into the sampler head at the front of that arm, and trapping it there—just moments before the spacecraft's thrusters would blast OSIRIS-REx back into space.

The team faced a critical technical issue: figuring out how to tell when the spacecraft physically impacted Bennu. Designing an instrument that could infallibly measure the distance between the spacecraft and the surface proved difficult. Because the team had only ever seen distant images of Bennu, they didn't have a clear idea of what its surface would be like. Without touching the asteroid, there would be no sample, but prodding the asteroid a bit too enthusiastically could destroy OSIRIS-REx.

So the team created three independent tests to pinpoint when the robot had touched the surface, Dworkin explains. First, they developed a timer that would mathematically calculate, based on the spacecraft's rate of descent, when it *should* have landed on Bennu's surface. Next, they added a physical mechanism, a spring to the TAGSAM arm that would compress when it encountered resistance. Finally, Dworkin says, they used navigation instruments which would measure the spacecraft's deceleration as the rendezvous happened. These instruments, they hoped, would serve as redundant backups to trigger TAGSAM's compressed gas cylinder to fire upon contact with Bennu.

By the fall of 2016, OSIRIS-REx was built and ready to fly. After numerous setbacks, getting to this point felt like a miracle.

At one point, the team accidentally sent the casing for one of the spectrometers, the Visible and Infrared Spectrometer (OVIRS), to a Los Angeles factory at the same time as its backup

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casing. Over the weekend, the whole factory burned down. Both casings melted, and the team had to fashion a backup to the backup, which was then used on the spacecraft, Dworkin says.

Then, components of the student-designed Regolith X-ray Imaging Spectrometer (REXIS) instrument were involved in a traffic accident. Luckily, nobody was injured, but those parts were never found.

Now, the spacecraft lay stacked atop a United Launch Alliance Atlas V rocket at Florida's Cape Canaveral Air Force Station, waiting for its September 8 launch. It was almost time to send OSIRIS-REx toward the heavens.

But then, just days before, a SpaceX Falcon 9 rocket that was being refueled on the adjacent launchpad exploded, sending a flood of debris ricocheting across the launchpad.

During the explosion, shrapnel struck the water deluge system, which floods launch decks to suppress damage from the rocket's flames, causing it to leak. That same system was to supply OSIRIS-REx's launchpad just days later; without it, the rocket would be unable to leave Earth. Due to the mission's complicated orbital trajectory, the next launch opportunity was a year away. "All space missions experience troubles, but this seemed like a lot," Dworkin says. Emergency responders worked around the clock to repair the damage.

By the time September 8 arrived, the launchpad had been

fixed, and the OSIRIS-REx mission finally launched on schedule.

The spacecraft was now charged with hunting Benu. The two-year journey to reach its asteroid target had begun.



AS THE SPACECRAFT ZIPPED through the solar system toward its target, DellaGiustina spent the summer of 2018 in Greenland on her own mission.

While the OSIRIS-REx team awaited images of Benu, she had joined a group of researchers performing experiments that might someday be conducted on the icy moons of Jupiter or Saturn. The team was stationed on a remote part of the Greenland ice sheet where polar bears were known to stalk their prey and where rescue by helicopter was at least a day away—if the weather cooperated.

DellaGiustina wasn't especially concerned about bears. Instead, Benu ruled her thoughts: "I remember thinking: I can't die before I see Benu! I have to see this asteroid!" By that time, she had spent almost





a decade working on the mission. Just like Lauretta, it seemed as though her career and ambitions were pinned on this single, daring spacecraft. Nothing would stop her from seeing it through.

When the 2.3-ton spacecraft reached Bennu in the second half of 2018, the team finally had a clear picture of the asteroid. Binzel says that this part of the mission never gets old. Before that point, celestial objects are usually "nothing more than tiny lights in space," he explains. "After literally decades of work, they become real worlds." There Bennu was, a diamond-shaped world filled with cliffs and valleys, craters and hills, shadows and light.

But these early images revealed that Bennu's surface was not like a sand-covered beach, as the team had hoped; it was populated with massive boulders, any one of which could tip OSIRIS-REx over during its sampling run. TAGSAM, the instrument responsible for sampling the surface, had only enough compressed gas for a handful of attempts. If the run on this geologic vault went awry, they could lose the spacecraft forever.

The team struggled to decide where on the asteroid to sample. The potential targets had to be both scientifically promising and safe enough for the spacecraft to visit. Looking at two-dimensional photographs of the asteroid taken by the onboard cameras didn't provide them with enough information about each location.

So, they called in a ringer—famed Queen guitarist Brian May. In addition to shredding guitars, selling out stadiums across the world, and being knighted by the King of England, May is a trained astrophysicist.

May's focus is stereoscopy—the practice of combining two flat images to make a 3D image. May and his colleague Claudia Manzoni melded multiple images of Bennu taken at slightly different angles to transform the asteroid into an eye-popping 3D object. Potential sampling sites looked flat in regular images, "but then Brian would send the stereo, and you're like, 'Woah, look at that, that's crazy—we could never get into there,'" says Lauretta.

This work helped narrow down the options to four landing sites. Keeping with the theme—Bennu is named after the living, avian symbol of the Osiris deity—these spots were also given bird monikers: Kingfisher, Sandpiper, Osprey, and Nightingale.

Ultimately, it came down to two choices. The engineers fancied Osprey, which lay along the equator and, lacking huge rocks, looked like a safe bet. Conversely, Nightingale was a fresher crater suffused with organic material, so scientifically speaking, it was considerably more valuable. But "Nightingale had a giant boulder," says Lauretta—one the size of a five-story building. "We called it Mount Doom."

A choice had to be made. OSIRIS-REx couldn't orbit Bennu forever, and they wanted to attempt this

only once. Osprey looked promising—but it wasn't bursting with that all-important prebiotic chemistry. They green-lit Nightingale. No guts, no glory.



ON OCTOBER 20, 2020, ENGINEERS

in Lockheed Martin's control room in Littleton, Colorado, sent a series of commands to OSIRIS-REx and, for what seemed like an eternity,

waited. "We were doing something that had never been done before," explains Sandy Freund, the OSIRIS-REx Spacecraft Mission Operations Manager at Lockheed Martin. "The moment we sent the spacecraft in and knew it was on its own—that period of time was probably the most stressful." Its autonomous systems had to work perfectly.

As OSIRIS-REx hurtled toward Bennu, the team held their breath. The 10-foot-long TAGSAM arm extended and slammed into the asteroid. The compressed gas cylinder fired, and debris flooded the collection chamber, nearly smothering the on-board cameras. But the spacecraft kept going, burying itself nearly a foot and a half into the asteroid's surface.

"The asteroid didn't cooperate," says Dworkin. Bennu's surface, it turns out, had the consistency of a children's ball pit. "It's digging down," Lauretta recalls. "It's not stopping." The spring inside the TAGSAM arm had failed. As the spacecraft didn't slow down, the detector measuring the resistance of the asteroid pushing back—indicating contact—also malfunctioned.

In the end, mathematics saved OSIRIS-REx. Based on the rate of descent calculations, the autonomous software correctly guessed when it was time to escape. The thrusters fired, the spacecraft launched itself into space, and the team—separated due to COVID-19 restrictions—erupted into cheers.

Their celebration, however, was cut short when they discovered the sample was leaking into space. A few chunks of the asteroid had wedged themselves under a membrane designed to keep the particles safely stored—and OSIRIS-REx was inadvertently behaving like a saltshaker. Once again, Lauretta and his crew found themselves in problem-solving mode.

Shortly before Halloween, a few days earlier than initially planned, they sent a series of commands to stow the leaking sample container inside a larger, hermetically sealed capsule—the object that, in three years' time, would fall back to Earth.

"Bennu itself seemed determined to literally throw as many obstacles in our way as it could," says Binzel. But they had triumphed, the sample had been stowed away, and OSIRIS-REx would begin its homeward voyage.

Scientists began to daydream about the sample.

⁴ NASA has repeatedly landed spacecraft at the Utah Test and Training Range, which lies approximately 80 miles outside Salt Lake City.

Binzel thought of it as a box of chocolates: "You can almost never go wrong with a box of chocolates." There's always something good in there.

THE JOURNEY OF OSIRIS-REX WAS FATED TO end, one way or another, on September 24, 2023. Its sample capsule was to fall on the Utah Test and Training Range, normally a place where military training and weapons testing is conducted. A landing here would be paradoxically safe and free from interruption by the outside world. But a soft landing is no simple thing. If anything went wrong, the capsule could careen into the ground and crack open like a Fabergé egg.

At around 2:00 a.m. local time, the team agreed to kickstart the autonomous landing sequence.

At 4:42 a.m., the cords connecting the capsule to the spacecraft severed, and the capsule began its descent. DellaGiustina, who had since become the mission's deputy principal investigator, reported back from Colorado: The batteries—vital for the descent operations of the capsule, including the parachute deployment—were online. Now, the team would have to wait four hours for the capsule to reach Earth's atmosphere.

"I'm familiar with what that wait feels like," explains Freund, who worked on two previous sample return missions built and operated by Lockheed Martin. Genesis, which collected particles from the solar wind, returned to Earth in 2004—but the parachute failed to deploy, and it smashed into the Utah desert. Stardust, which gobbled up matter from a comet, came home in 2006—its parachutes granted it a soft landing. "I've seen Genesis and Stardust, right? I've seen this go both ways," Freund says, noting that OSIRIS-REx was built atop Stardust's success. "We expect this to be nominal but are prepared if it is not."

At 8:42 a.m., the capsule hit the atmosphere and violently decelerated, heating up to 5,000°F as it rushed across the California sky toward Utah. The force of the impact triggered a shockwave that thundered across the American southwest.

After two minutes, it was time for the drogue parachute to unfurl. But nobody seemed to spot it. One minute passed. Then another. High-altitude monitoring planes had caught the infernal capsule on their infrared cameras. Still no drogue. Lauretta, from his vantage point in the nearby helicopter, didn't have access to this footage. All he heard was ambiguous commentary in his ears, partially drowned out by the noise of whirring blades.

The clock ticked over to 8:47 a.m. Nothing—then a voice booms over the radio: "We have confirmed parachute deployment." Orange and white fabric billowed out from the capsule. Lauretta, overcome with emotion, burst into tears.

Just five minutes later, the capsule gently touched down on the Utah scrub.

A U.S. Air Force explosives ordnance expert, tasked with ensuring there was no live artillery near the landing site, approached first. All clear. Next, a safety officer from Lockheed Martin checked that the capsule wasn't leaking any noxious fumes from, say, ruptured batteries.

Finally, at 9:45 a.m., Lauretta walked up to the capsule and calmly inspected it.

After bagging the capsule, the team attached it to a helicopter's longline and flew it, dangling above the desert, to a temporary clean room at a nearby military base. Engineers pumped inert nitrogen gas into the capsule, ensuring no terrestrial contamination could seep in, and began preparing it for transport.

Later that day, during a press conference, the wired Lauretta says that, back in 2004, the idea of stealing material from an asteroid "seemed like magic." Today, he says, "is the end of a very long spell." In the end, science made that magic real. "And boy, did we stick that landing," he declares, with a grin.

Then his thoughts turned to Michael Drake, the mission's architect: "He would have loved today," Lauretta says.

THE NEXT DAY, THE TEAM FLEW THE sample to NASA's Johnson Space Center in Houston, Texas, and stowed it in the sample curation laboratory, which was designed specifically for the OSIRIS-REx mission.

But even after the sample had been safely brought back to Earth, a darkly comic late-stage curveball delayed some of the first in-depth scientific analyses. Two of the sample container's 35 fasteners remained stuck, meaning much of the material was inaccessi-





ble. NASA engineers scrambled to develop new tools to overcome this issue—space-age wrenches that wouldn't contaminate the sample container. Scientists finally removed the pair of faulty fasteners in January 2024.

Just two months later, scientists began their preliminary examination of the grains. Even though they've studied only one percent of the grains, they could already see tantalizing clues about the asteroid's dramatic past: A chemical analysis of the fractured grains revealed Bennu was once part of a larger world that sat beyond the orbit of Jupiter and at one time had flowing water. This world, researchers discovered, was forged from the sometimes-explosive deaths of multiple stars and contained organic material that formed before our sun ignited. Long ago, a catastrophic collision snapped Bennu off of its parent body, the near-Earth asteroid we know today.

There is so much more yet to be unveiled. Over the next few years, the 4.29-ounce sample will be distributed to researchers at laboratories around the world. Up to a quarter of it will be given to the 233 scientists on the OSIRIS-REx team, who are scattered across 38 institutions on four continents. And just as JAXA donated some of Ryugu to NASA after Hayabusa 2 safely returned, so will NASA hand over some of Bennu.

A hefty portion of the material will enter a deep

chill for up to half a century, unobtainable by anyone. There's precedent for this: Some of the Apollo-era moon rocks were preserved for 50 years so that they could be studied by scientific techniques that didn't yet exist. The same will apply to much of the Bennu sample. "You need to always be thinking of scientists who'll be smarter than you, and will have access to better equipment," explains Jessica Barnes, the University of Arizona cosmochemist.

The spacecraft, meanwhile, is moving on to its next task: investigating another asteroid—not for cosmochemical clues, but to learn how to better protect Earth. Twenty minutes after it separated from the capsule, OSIRIS-REx veered away from Earth and transformed into OSIRIS-Apophis Explorer, or OSIRIS-APEX, a mission now commanded by DellaGiustina. In 2029, it will swing by the eponymous 1,100-foot-wide asteroid Apophis. It is an opportunistic bit of reconnaissance designed to bolster our planetary defense knowledge—to know thine enemy, in other words.

Lauretta is happy to see the spacecraft depart. There's plenty of work to be done here on Earth. Those grains won't answer all of his questions—about the origin of life or our solar system's early years—but the best clues yet could soon be revealed, thanks to a mission that, long ago, sprang to life as a sketch on the back of a cocktail napkin. ■

A small portion of OSIRIS-REx's sample will be displayed at Space Center Houston in Texas.





Upgrade Your Living Room With This DIY

MID-CENTURY

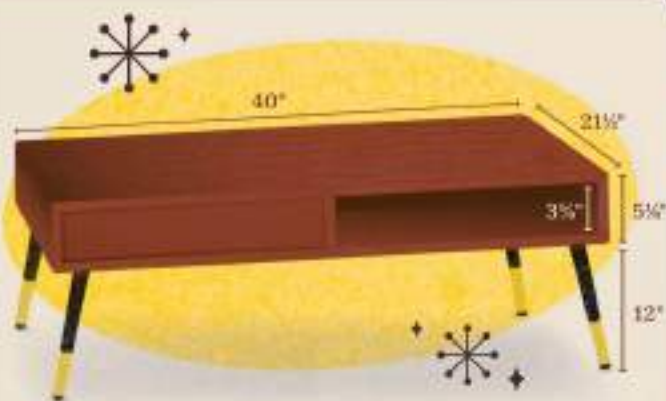


This project
is easy to
build and
customize to
fit your space.

BY BRADLEY FORD

PHOTOGRAPHY BY
THOMAS HENGGE

COFFEE TABLE



MATERIALS

- ☐ 3/4" x 7 1/4" x 8' clear pine (x3)
- ☐ 3/4" x 3 1/2" x 8' clear pine
- ☐ 1/2" x 2' x 2' lauan plywood
- ☐ 12" angled tubular table legs (x4)
- ☐ Titebond III wood glue
- ☐ #10 x 1/4" screws (x16)
- ☐ 1" finishing nails
- ☐ Wood stain
- ☐ Satin polyurethane or finish of your choice

TOOLS

- ☐ Circular or track saw
- ☐ Miter saw, optional
- ☐ Table saw, optional
- ☐ 24" bar clamps
- ☐ Dowel jig kit
- ☐ 24" clamps, 2 or more
- ☐ Drill
- ☐ Router with 1/4" round-over bit
- ☐ Random-orbit sander
- ☐ Sandpaper (100, 150, 220, & 320 grits)

Y

ou might say mid-century modern (MCM) furniture is having a moment, again. Social media platforms, like Instagram, are helping to drive the design trend's resurgence. From bespoke makers to thrifters hunting for period pieces to flip, and fashionable interior designers—clicking on one may cue the algorithm to deliver a deluge of content, relating to this nearly century-old design trend. If you've admired MCM from a distance but didn't know where to start with it, here is an opportunity to build a piece of your own.

This MCM-inspired coffee table was designed with cost, flexibility, and ease of construction in mind. The project uses simple joinery and common tools, so it doesn't require a lot of woodworking experience. The most important thing needed is patience—measure twice, cut once, as they say.

You can customize this coffee table in numerous ways. Swap out the species of wood, type of finish, or style of legs to suit your taste. You could even alter the dimensions to work better with the length or height of your sofa—the construction process remains the same. For our example, we chose clear pine boards to keep cost low. Traditional MCM furniture often uses teak, oak, or walnut, but you could also use poplar, which is reasonably hard and durable and won't break the bank.

GLUE UP

Create the top and bottom of the coffee table by cutting the three 7 1/4"-wide boards in half [1], giving you six 48"-long pieces. Select three with similar grain for the top. Follow the directions from the doweling jig kit for edge-joining both sets of three pieces. Use the 3/16" dowels and drill bit, and place the holes at 5", 14", 24", 34", and 43" [2]. Glue, clamp, and allow 24 hours to dry. Then carefully scrape off any excess glue [3] and sand to be sure all seams are flat.

TRIM PIECES TO FINAL DIMENSIONS

To ensure the top and bottom are the same size, stack them, flush along one long edge and close to even on one end, and clamp them together. Then cut them together. Cut the width to 21 1/2" (long edge to long edge), then cut one end square, removing as little as possible [4]. Cut a 3 3/8" strip off for the two sides, and a second 3 3/8" strip for the center divider—you'll end up with an extra piece. Finally, measure 40" to the other end and cut square—giving you two 21 1/2" x 40" pieces. For precise cuts, use a track saw or circular saw with a makeshift fence clamped to the board.





WHAT EXACTLY IS MID-CENTURY MODERN?



Mid-century modern is a design trend from the mid 1900s that, surprisingly, never really went out of style. It was influenced by the Bauhaus art movement, where ornamentation is shunned, and form follows function. MCM's core characteristics are simple, functional shapes, clean lines, and a lack of embellishment. MCM design can apply to architecture, but for most people its most accessible and recognizable form is seen in furniture.

Materials are another hallmark of MCM design. Wood, often teak, but also oak and walnut, was frequently used, as well as plywood. Additionally, newer materials like plexiglass, fiberglass, and vinyl have been used, as well as glass and metal. The various materials are often used in a way to highlight their contrasts in color or texture. A large part of MCM furniture's popularity is due to its timeless, modern vibe—that, plus its simple design, means it is adaptable and can blend in with other styles.



ASSEMBLE COFFEE TABLE

Arrange the pieces to mock up the coffee table and label them "top," "left," "right," "center," and "bottom"—to maintain the correct orientation. Lay out the dowel placement, using four on the top and bottom of the ends and three on the top and bottom of the center divider. Space the dowels evenly, starting and ending 2" from the outside edges. To mark a centerline on the top and bottom, stack the boards and mark the center on both sides, then flip the top over and connect the marks. Use the doweling jig to drill the holes into the pieces [5]. Assemble from the bottom up by gluing [6] and joining the ends and middle first, then add the top. Use cauls, or scraps of wood, to protect the surfaces when clamping [7].

BUILD THE DRAWER

From the $\frac{3}{4}$ " x $3\frac{1}{2}$ " x 8' board, cut two 18" pieces for the fronts (yes, this drawer has two fronts; it can be opened from either side), and two 20" pieces for the sides. All four pieces will need to have a $\frac{3}{4}$ " x $\frac{3}{4}$ " rabbet (a step or channel) on the same side, on each end. This can be done in multiple passes on a table saw [8]. All pieces will also need a $\frac{3}{4}$ "-deep groove, $\frac{1}{4}$ " wide, to accommodate the plywood drawer bottom. This can also be done on a table saw, with two passes [9]. Cut the groove $\frac{1}{4}$ " from the bottom, on the same side as the rabbet. The sides will sit inside the rabbets on the fronts, flush with the ends. Assemble the fronts and both sides. Glue the rabbets and use finishing nails to hold them together [10]. Cut the luan to 20" x 17" and slide it into the grooves—but don't glue it [11]. Finish the drawer by installing the back and securing in the same fashion with glue and finishing nails. Check for square.





ROUND-OVER TABLE EDGES

Using the $\frac{3}{8}$ " round-over bit in a router, rout all the outside edges of the table [12]. Test the bit on a scrap of wood to get the depth right so there is a smooth transition on the radius where it meets the top and side. Be sure to move slowly when approaching the corners to prevent blowout. Sand all surfaces, especially the transitions where rounded edges meet flat areas [13]. With the exception of end grain, be sure to sand with the wood grain.

INSTALL THE LEGS

Use $\frac{3}{4}$ " screws to mount the legs to the bottom of the table. Position the legs 1" in from the side and end at each corner [14] to accommodate their angle and ensure the tips align with the ends of the table [15].



JOINERY OPTIONS



We chose to use dowels to locate and glue the joints in this project. Doweling jig kits can generally be found for less than \$25. They are perhaps one of the most affordable ways to ensure alignment of edge or corner joints—plus they don't require investment in any other special tools. The only thing you need is a drill.

You can also use a biscuit joiner and wood biscuits to make precise corner and edge joints. Biscuit joints will be a little more accurate, but the tools to cut the slots cost \$60 or more.



APPLY FINISH

Finishing is entirely up to you. Depending on the wood species you chose, you may want to stain it [16], or use a clear finish to let the natural color shine through. If you are going to stain the wood as we did, first use a pre-stain conditioner, which will help the wood absorb the color evenly. Apply stain evenly using a soft, lint-free cloth or staining pad, and allow it to dry thoroughly. MCM furniture finishes are usually rather flat, so we used a satin spray polyurethane. Apply two coats, and then sand very lightly with 400- to 600-grit paper when dry [17]. Apply two final coats of polyurethane [18]. Don't worry if it doesn't look too smooth, because it will flatten out as it dries. You could also finish with tung oil or Danish oil, rubbed out with steel wool and butcher's wax. ☐



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SKINWALKER RA



BY DAVE HOWARD PHOTOGRAPHY BY RUSSEL DANIELS



The 512-acre ranch has captivated
real-estate tycoons, TV producers, and the U.S.
government. What are they searching for?

RANCH REVEALED



HAVE BEEN WARNED. THIS MUCH IS CLEAR within minutes of ducking out of a helicopter onto the high-desert oasis of Skinwalker Ranch in northeastern Utah one searingly bright October afternoon. As a visitor approaching the dark and inscrutable paranormal forces patrolling this property, I could be targeted.

The admonition has come in several forms. There was the prayer for safe deliverance given by chopper pilot Cameron Fugal, brother of property owner Brandon Fugal, as we approached the ranch. This didn't necessarily rattle me, as I'd recently watched Cameron deliver a similar invocation on season one of *The Secret of Skinwalker Ranch*, the hit History channel show that has generated mainstream attention for the property.

There was the surreal experience of being greeted on the helipad by about half the show's cast, whom I felt I'd come to know during my hours of binge watching—standing stone-faced and shoulder to shoulder like some official tribunal ready to deliver grim news. Long-suffering ranch superintendent Thomas Winterton, looking typically Marlboro Man, shook my hand first, followed by glowering security chief Bryant "Dragon" Arnold. Erik Bard, the spritely scientist, and red-bearded security man Kaleb Bench chatted nearby. It was as if my arrival was the only thing holding up the start of the season five shoot. When we go inside, Winterton presents me with a liability waiver, which strikes me as highly unusual—there's nothing on the day's agenda beyond an in-depth conversation.

But what truly tweaked my antennae was a conversation I'd had an hour earlier, at the Fugals' hangar in Provo. Brandon was on the phone, tending to his day job as a commercial real-estate titan,

and Cameron and I were chatting amiably when he suddenly pivoted from a story about becoming a grandfather. "Every time we bring somebody new, the ranch interacts a little different," he said. "Usually it's been mostly mild. I wouldn't worry about it too much." This struck me as a roundabout way of saying I should at least be a little worried.

"We've had some guys that are like, 'This is so stupid—we're gonna show those aliens who's boss...'" he continued. "And it's messed with them."

"What happened to those guys?" I asked. "Something physical, or their cell phones wiggled out, or—?"

It was indeed bodily harm, Cameron said. The previous owner, Robert Bigelow, was haunted by the place, both during his time there and after, when "all the negativity followed him home," Cameron explained. This sounded a little like the aftermath of a bad Red Lobster meal, but I'd seen the entire series at that point, and I knew what he meant. I'd just never thought of it happening to me.

During the flight, as Brandon recounted the particulars of acquiring the 512-acre ranch, I mentally rifled through the catalog of hazards the show has intimated: unidentified anomalous phenomena (UAP, which is the modern term for UFO); cryptic messages transmitted through sound waves or electromagnetic interference; and, possibly most relevant, those weird injuries, including vertigo, nausea, temporary paralysis, hearing impairment, and disorientation, some of which led to hospitalizations.

Shortly after we arrive, I inquire about the ranch's tendency to identify and punish skeptics. The crew immediately warms to the topic. The visitors with the most serious health effects, Winterton says, "are the ones that came—myself included—with kind of a cavalier attitude of, 'There's nothing here that's gonna bother me.'"

It's possible the group has inferred a certain skepticism from my request, a few weeks earlier, to camp overnight at the ranch—an inquiry that Fugal shot down, citing liability and safety reasons. Can the capricious forces patrolling the property intuit my thoughts? It sounds a bit fantastical, but after hearing about other skeptics' experiences, I'm not so sure anymore.

But as with seasickness and combat, there's no way

Erik Bard, one of the show's scientists, stands in the triangle, a region reportedly high in paranormal activity. It is one of the most-observed places on the 512-acre ranch.



to gauge in advance how you'll fare until you're in the thick of it. The only thing I know for sure is that I'm about to find out.

Prior to my arrival at the ranch, the most unnerving thing I'd experienced was Brandon Fugal's driving. He had picked me up that morning in Salt Lake City in his Lamborghini Urus Performante. Soon we were hurtling south on I-15 at 90 miles per hour to his airport hangar, while he expounded on his skepticism over TSA screenings and Covid-era face masks.

Halfway to Provo, he explains that he acquired Skinwalker Ranch as an "open-minded skeptic. I believed that there was most likely a natural explanation for all that had been reported. I had never seen a flying saucer or anything of the sort." The

Lambo touched 99 as he veered right to blow by a car dawdling along at 90.

Just like on the show, Fugal wore a fitted suit with a crisp, white dress shirt, fancy cowboy boots, and trademark wire-rim glasses—Harry Potter meets Gordon Gekko. He leans into the narrative arc of the hard-charging business icon: He says he started in real estate at age 18 and sold his first office a year later, works 16- to 20-hour days, and has since reshaped Salt Lake City's skyline. He reveres Elon Musk and frequently name-drops rock stars and politicians in his orbit. (He hired the band Air Supply to play at his 2021 wedding.) Fugal describes himself as a 1980s teenager in a 50-year-old body, and boasts a vast collection of rare books and film memorabilia, including a full-size exoskeleton from the set of *Terminator 2*. And, most relevant to Skinwalker, he uses



"THE SECRET OF SKINWALKER RANCH" IS A SUMPTUOUS BUFFET FOR CONSPIRACY-DRIVEN UFOLOGISTS AND PARANORMAL ENTHUSIASTS, UNABASHEDLY SPLICING SUPPOSITION, FOLKLORE, AND UNEXPLAINED SIGHTINGS INTO A SERIES OF HIGH- AND LOW-TECH EXPERIMENTS.

his fortune to underwrite certain science-driven moonshots.

In 2009, Cameron had just landed his brother's private jet when, on a whim, Brandon asked him: How old is the technology and the physics behind this jet-propulsion system? The answer—the 1940s—shocked him. Fascinated by the question of how science had stalled in that realm, Brandon began researching alternative forms of propulsion, which led to a brief partnership with a former client, Joe Firmage, an early internet entrepreneur and UAP aficionado. Firmage claimed he was on the cusp of breakthrough technologies that enable purported UFOs to move in unorthodox and physics-defying ways. The project cratered, but in the aftermath Fugal was introduced to Robert Bigelow, a maverick billionaire who used his Las Vegas real-estate fortune to build a private aerospace firm. Bigelow Aerospace developed an expandable habitat for astronauts on the International Space Station before shuttering operations in 2020.

Bigelow, who has also espoused the presence of aliens and UAPs, is largely responsible for putting Skinwalker Ranch on the map. Established as an agricultural homestead in 1905, for more than a century the ranch experienced reports of strange activity, and as a result had been named for shape-shifting witches of Navajo lore. As early as 1911, a newspaper reported locals hearing "strange noises" emanating from the property, and a string of subsequent owners reported UAPs or other strange activity. Bigelow purchased it in 1996 from ranchers Terry and Gwen Sherman, who

had been so spooked by their experiences there—which included UAP activity, cattle mysteriously slain, dire wolf-type creatures, and glowing orbs they say vaporized their dogs—that they eagerly unloaded the place.

Fans can tune in and watch live feeds from the cameras that surround Homestead 2, the site of several paranormal occurrences.

Around the time he purchased the property, Bigelow founded and bankrolled the National Institute of Discovery Science, with the goal of conducting serious scientific study of UFOs and other paranormal activities at Skinwalker and beyond. He quickly installed a network of investigators who reported their own paranormal happenings at the ranch. A book written by chief investigator Colm Kelleher and news anchor George Knapp describes one incident in which something had disgorged the wiring within a closed-circuit ranch video camera while another camera, trained on it, captured no activity. The team produced another report detailing the 1998 killing of a perfectly healthy three-year-old cow. There were no signs of struggle and no tracks found, but the animal was missing its left eye and part of its left ear. Additionally, its heart was shredded, but its pericardium—the sac that encloses the organ and its major vessels—was intact.

Bigelow's project later morphed into the Pentagon-funded Bigelow Aerospace Advanced Space Studies program. From 2008 to 2013, the program recorded more than 530 instances of paranormal activity witnessed by more than 150 people.

When Fugal met Bigelow in Las Vegas, he only knew what he'd read in Knapp and Kelleher's book, and he told Bigelow he thought what had been seen at the ranch "was the product of groupthink mixed with misidentifying naturally occurring phenomena."

By that point Fugal was leading the largest commercial real-estate enterprise in the intermountain west, with 30 offices in 11 states. He didn't expect that alien sightings and disemboweled livestock would play well in his rarefied circles. "I did not want my name associated with these topics," he says. But Fugal was intrigued, and after a series of lengthy conversations with Bigelow in 2016, he quietly bought the ranch for about \$500,000 through a shell corporation called Adamantium Real Estate, named for the fictional alloy used to make Wolverine's claws in Marvel Comics. Several days before the closing, he flew out to see the ranch for the first time and was stunned by the dramatic landscape: the high-desert mesa plateau, the snaking course of Dry Gulch Creek, the clutch of dilapidated pioneer homesteads evoking a complex history.

He'd been an Eagle Scout growing up and was now on the board of the Utah National Parks Council of the Boy Scouts of America. He figured he'd have a scientific team determine there was nothing untoward about the property, then he would donate it for scout camps and youth programs.

But before he could put that plan in motion, things started happening.



We settle into the main room of the Skinwalker Ranch headquarters, and the conversation naturally drifts toward the crew's conversion stories, meaning the experiences that led them to believe that strange forces are afoot here.

Winterton, the ranch superintendent, grew up in the Uinta Basin, the geological feature that encompasses Skinwalker. His first time there—as a nonbelieving building inspector—he experienced severe vertigo and light-headedness. “I finally had to back up against the wall and then I kind of slid down towards the floor,” he says.

None of these tellings is more compelling than Fugal's. In 2016, an employee recorded a UFO sighting on his phone's camera, snapping pictures of a horizontal object in the sky at a time when flight data showed there was no commercial or private air traffic over the ranch. The employee reported it to Fugal, who immediately began studying the images. Four months later, Fugal says he and two security guards saw a silver-gray spaceship-type object moving erratically above the mesa that borders the property.

And thus Fugal made the shift—in his words—“from being a healthy skeptic to an experienter.” Since then, he has intensively pursued an understanding of what he describes as “high strangeness.” He erected a gate to seal off the property, installed a web of security cameras, and has poured millions of dollars into advanced technological instruments aimed at quantifying the ranch's mysteries.

Erik Bard, an X-ray physicist, is one of the lead experts Fugal hired to harvest and interpret the reams of data these instruments have produced. Before moving to the ranch full-time, Bard was a partner in a firm that makes components for machines that produce or measure X-rays; many of its products go to the national labs, he says.

Bard has his own conversion story. He had dismissed what he'd heard about the ranch as “E.T. interdimensional religious whatever.” Then Fugal invited him to visit in October 2016—coincidentally, the same day that Fugal saw the UAP—and two things happened: On a trek out to the mesa, Bard pulled out his phone to take a picture and saw that the screen was flickering. At first, he thought he had broken it.

When he and others in his group returned to the homestead, Bard says he couldn't keep his balance, and several others said they felt the ground spin. “The interesting

thing is, I hadn't told them that I was experiencing it,” he recalls.

Bard figured he'd try to make sense of these occurrences using science. First, he examined the phone malfunction. In an area with poor reception, a smartphone's RF (radio frequency) components emit extra energy working to connect to a cell tower, which can interfere with other parts of the unit. Bard thought this was a perfectly good explanation, except that he couldn't reproduce it. Several months later he tried a different experiment using a powerful rare-earth magnet capable of lifting 1,750 pounds of iron. When he put his phone on the edge of the magnet, he reproduced the effect.

The answer seemed to be the ranch's unusual electromagnetic field, and specifically, a phenomenon called electromagnetic interference. In subsequent years, he and others have repeatedly dealt with more instances of what he experienced on his phone. Drones have mysteriously crashed; batteries on phones and other devices—ranging from boom microphones to H4n recorders—have suddenly drained. The ranch's computer and surveillance systems have malfunctioned. These glitches haven't just impacted the ranch's equipment, Bard says, but also the equipment being brought in by outside experts.

Bard, who is more engaging and animated in person than on TV, read that strong magnetic fields also affect the human nervous system. MRI technicians, Bard explains, experience many of



Beth Bard (left) and ranch owner Brandon Fugal (right) claim to have had strange encounters.

the same symptoms that people have at the ranch, including vertigo and nausea. These studies plus his benchtop experiment pointed to a magnetic field anomaly. "That was the beginning of trying to put a physics interpretation on some part of the phenomenon," he says.

The source of the electromagnetic activity is another question: Bard speculates that it could be linked to some physics quirk in the space-time realm or something technological—a cloaked craft or UAP. Bard is still hunting for answers.

Bard's super-magnet experiment is only one of the myriad scientific forays into the site, as the show's viewers know well. It's possible that no wild space in the country has been as closely scrutinized as this one. Just about everything across the landscape has been analyzed, poked, and sampled.

The crew has deployed hyperspectral imaging technology, which reveals light on parts of the spectrum humans can't otherwise see. There are aircraft transponder data receivers; laboratory-grade thermographic imaging systems; advanced magnetometers; forward-looking infrared (FLIR) cameras, which detect infrared radiation and convert it to an image; and a geophone-based near-field seismometer, to ensure that no seismic wave goes undetected. Much of this tech is military-grade, Fugal says.

The team has mapped every inch of the ranch using a combination of LIDAR, drone-based photogrammetric mapping, and ground-penetrating radar. They've collected and analyzed samples using X-ray fluorescence. At one point, Bard and his crew brought in a team to aim high-powered optical lasers—devices colorfully known as a laser space cannons—at the sky above the ranch to search for more evidence of whatever invisible forces may hover overhead.

Curious findings keep the crew—and viewers—energized. Bard beckons me into the control room to show me what one of the simpler pieces of equipment—a surveillance camera stationed in Homestead 2—harvested. Feeds from the 50 or so audio-enabled security cameras across the property are available to Skinwalker Ranch Insiders, which is essentially a fan club. For a membership that starts at \$8 a month, participants get access to "disturbing & anomalous audio, infrasonic, & frequency data," according to the website. The more than 10,000 Insiders who have so far subscribed also get 24-hour access to the ranch webcams. Not only that, Bard has steampunked the system so that they are also able to control the cameras, and swivel

them if they spot something. This has essentially created a community of volunteer citizen scientists. ("It's like giving someone the keys to the International Space Station and being able to steer it around and position and explore the cosmos," Fugal says.)

One Insider reported what Bard shows me now: At 1:39 a.m. one night, a door on Homestead 2 abruptly slammed shut. There was no wind, and no sign of anyone on camera. Played on repeat in grainy night-vision video, it's undeniably creepy.

It wasn't always obvious that a TV show was the way to go. Fugal says after he was approached by the History channel in 2018, he only agreed to the show on three conditions: Nothing could be faked; the film crew had to use the investigators he'd hired; and his identity was to remain secret. The History Channel team agreed to the first two mandates—the show's creators say that any staged reenactments are based on eyewitness accounts—but rejected the third, when the producers convinced him the research would only be believable if there was full transparency.

As it happened, the world was changing fast regarding perceptions of such phenomena—in particular, UAPs. Owing to a surge in military-pilot sightings, whistleblower pressure, and media coverage, UAPs were being legitimized in Congress and acknowledged more openly by the defense and intelligence communities, shifting the phenomena from the tinfoil-hat realm into the cultural mainstream.

In 2018, Fugal and his team, including three scientists, shared some of the data they'd collected with the Senate Select Committee on Intelligence and the Armed Services Committee in a confidential briefing in Washington, D.C. Fugal says he maintains contact with Utah's senior senator, Mike Lee, and the state attorney general, Sean Reyes. "There has been a seismic shift in the way the government is approaching the topic," he says.

But government knowledge is still largely

A suite of military-grade instruments—everything from magnetometers to optical lasers—dots the landscape.

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blanketed in secrecy, and Bigelow's findings on the ranch have similarly remained hidden from the public, even to Fugal; the program was secretly funded by the Pentagon, and its contents remain undisclosed. This is partly why he pivoted in the opposite direction. Everything his team learns is shared openly, he says, through the show or the phalanx of cameras, or both.

This was a canny move, to not only be transparent with what was going on there but to make transparency part of the point: *Maybe you don't believe in this, but you can believe in how we're doing it.* For a curious public starved by generations of government intransigence, this has been raw meat tossed to hungry wolves. "People want brutal honesty," he says—and 2.22 million viewers tuned into the 2023-'24 season, making it the 10th most popular non-sports cable program.

Fugal says he's never taken a penny for the show—that he's given it all to charity and put it

back into the ranch equipment. But he is clearly an adroit businessman with a nose for opportunity; soon after purchasing the ranch, he trademarked the name for purposes of the TV show and for use on merchandise such as T-shirts and mugs. The show has made him a celebrity—it "has turned my world upside down," he says. He was even recognized on the street during a recent trip to France and Italy.

It's clear he has fully shed any reservations he once harbored about serving as Skinwalker's front man. On the show, he drops lines like "We'll come to understand the dark forces that we're interacting with, but also the nature of our world and our reality" without a hint of self-consciousness. He's a rabid fan of 1980s science fiction; one of his prized possessions is a copy of the *E.T.* screenplay. What better way to feed that appetite than to hypothetically possess his own E.T.?

Fugal says he's often asked what he believes they

**MAYBE THE REAL FANTASY OF SKINWALKER RANCH
ISN'T THAT ANSWERS TO THE STRANGE OCCURRENCES
WILL BE IDENTIFIED, BUT THAT THEY WERE
EVER IDENTIFIABLE IN THE FIRST PLACE.**

are dealing with. Could it be extraterrestrials? Multidimensional beings? Or some spiritual influence? "I answer it's likely D: all of the above," he says. The data they've collected over the years suggest there could be a wide range of origins and agendas associated with the phenomena. "The deeper the investigation digs both literally and figuratively," he says, "the more complicated it becomes."

By the time we wander out for a tour, the landscape is so dazzling I find it hard to muster much concern for my safety. The sky is vast and clear and the cottonwood trees are gilded in autumnal splendor. As we walk through and around the tumbledown homesteads, I pay particular attention to the largest of the three buildings that comprise Homestead 2—the site of the mysterious slamming door spotted by a Skinwalker Ranch Insider.

From the outside, the doorframe is dark and vacant, like a missing tooth; the modest two-room shack, now more than a century old, has gradually submitted to the forces of weather and age. Inside, leaves are scattered across the floorboards, and sunlight glides through the failing ceiling as if filtered through a julienne slicer. I see no evidence of wires that could have been rigged there to cause the sudden, unexplained movement. Gusts often cause doors to swing shut, but this one closed from the inside; the windows are empty cavities and there's a hole in the roof, so there would be no way to build up any air pressure inside. The camera had shown the whole room, and nothing had moved prior to the door opening. "Look at the debris on the floor," Fugal says. If it had been windy, leaves and other detritus would have been blowing everywhere.

It's fascinating, but there's no way to make sense of it, and little time to linger. Moving around in Rhino-type vehicles used on the show, we cruise over to the "Triangle." Investigators zeroed in on this patch of otherwise unremarkable land between the headquarters and the homesteads as a potential hotbed of paranormal activity during the show's latter seasons after chronicling unexplained interference with helicopter flights, drones, and other forms of aerial exploration.

The site consists of a set of jeep roads that form its geometric namesake, but we didn't bother

walking around; most of what makes the location interesting—at least for fans of the show—is invisible. The cast filled entire episodes with experiments that included elevating a squadron of drones and shooting rockets skyward to see if they could figure out what was occurring in the airspace above. These experiments have led the group to believe there may be some sort of interdimensional portal. It sounds far-fetched, but millions of viewers keep coming back for more.

Cinematic as all of this is, what none of this technology has been able to provide so far is much in the way of concrete answers. *The Secret of Skinwalker Ranch* is a sumptuous buffet for conspiracy-driven UFOlogists and paranormal enthusiasts, unabashedly splicing supposition, folklore, and unexplained sightings with a series of high- and low-tech experiments. The result is a kind of true-believer cut-up, and viewers may feel they've learned a lot but have no clue what any of it amounts to.

Five seasons in, one question that emerges is whether a force intelligent enough to avoid detection, or reveal itself at will, can ever be identified. This plays into the producers' hands, of course; a malevolent force that can reveal itself in opportune moments yet avoid detection drives the need for more investigations, and more television seasons. It creates a waves-against-the-shore rhythm, in which the cast experiences something, excitedly conducts a series of experiments—only to wind up, in some cases, with more questions than they had before. The tide advances and retreats, continually polishing the ranch's legend in the process. But how long can they maintain the tension, and keep the audience entertained, while concrete answers remain just out of reach?

The next day, Fugal revs up another one of his toys—a Ferrari 488 Spider—for a final lunch meeting. Just before we leave the restaurant, I ask him something I've been pondering since he turned down my camping request: Will he even reopen the ranch to the public? Let us see for ourselves?

He shakes his head. Having a secure, living laboratory, he claims, will allow us to develop insights that could change the course of history. "I know that sounds like hyperbole, but you look at the topics we're discussing, the implications," he says, "if



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you don't understand the weight and significance, then you perhaps are not... I think the appropriate way to say this is, you're not ready."

If the public at large is frustrated by this, they're not showing it. Yes, there are some snarky reviews, but Fugal says he's selling plenty of hats, DVDs, and T-shirts. The crew was about to start shooting a sixth season, and the series has spun off into *Beyond Skinwalker Ranch*, a History channel show that will probe other paranormal hotspots.

Maybe I'll never be ready myself to grasp the significance of the site in the way that Fugal has. But my visit, in the end, did suggest one potential explanation for the enduring nature of this phenomenon. Maybe the real fantasy of Skinwalker Ranch isn't that answers to the strange occurrences there will be identified, but that they were ever identi-

fiable in the first place.

Here's what I can report: I never felt dizzy or experienced any sudden pain. I did not exit the ranch anxious that I was being shadowed by some unknowable force, nor did my phone or digital recorder glitch. But I did *feel* something. It was the same thing I'd experienced coming off gigantic, twirl-you-upside-down amusement park rides—the ones where the caution signs are a little larger, and even though they're for legal purposes, they add a fizz of danger. You know the sensation: You unbuckle and your hair is blown back and you feel buzzy from the thrill. Maybe, if you're a fan of *The Secret of Skinwalker Ranch*, it's the same feeling you have watching the show, in its best moments.

Are there really UFOs and dire wolves haunting this lonesome patch of high desert in eastern Utah? In the end, for millions of fans, the answer may not really matter. 

The History Channel and Prometheus Entertainment began filming on the 512-acre ranch in 2019.

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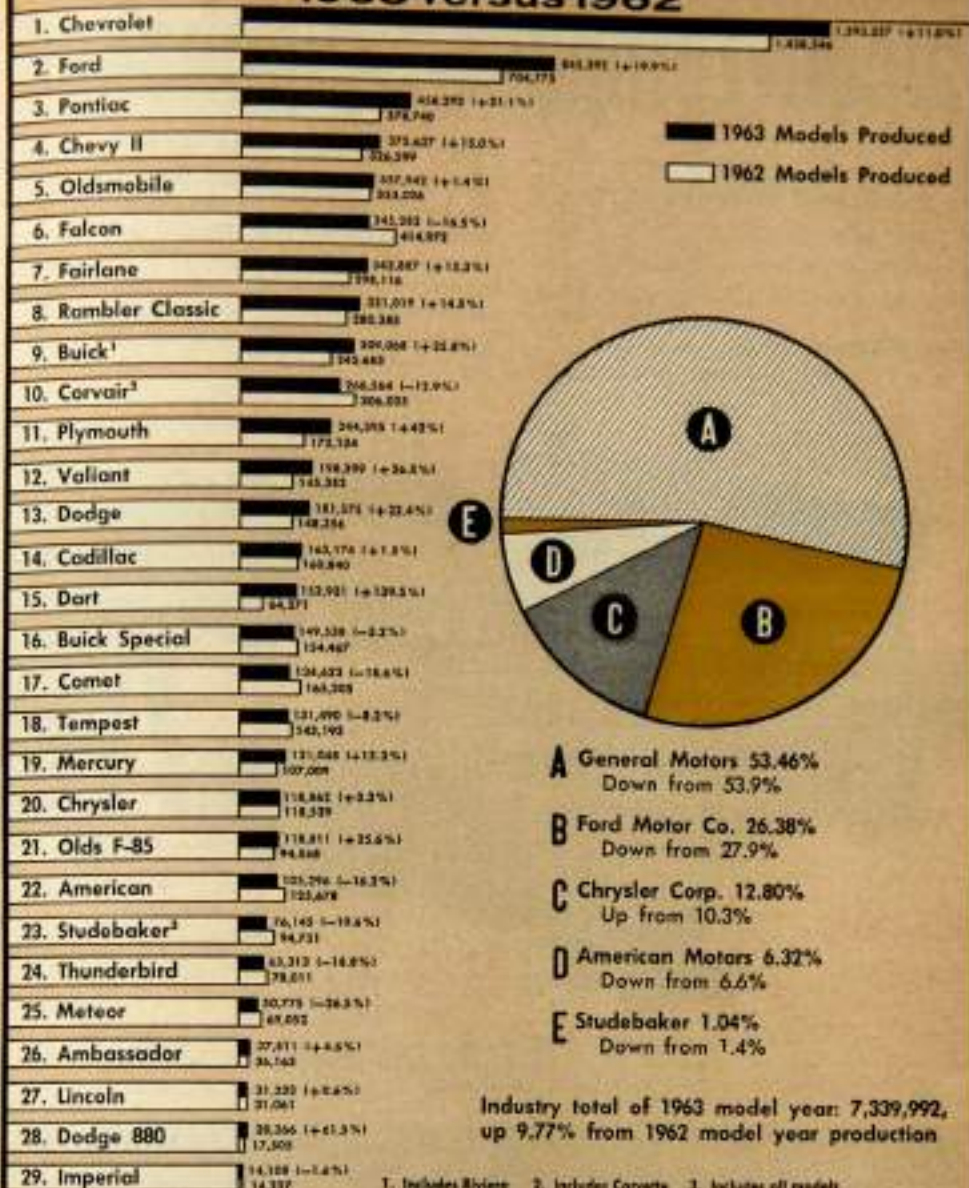
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air had been reheated over and over again, Charlie Nash was unenthused about the developments of his chief engineer, Meade Moore. But Moore's heating system got a major boost when an aging Nash brought his, would George Mason to Nash's presidency by merging with Mason's



PRODUCTION BOX SCORE 1963 versus 1962

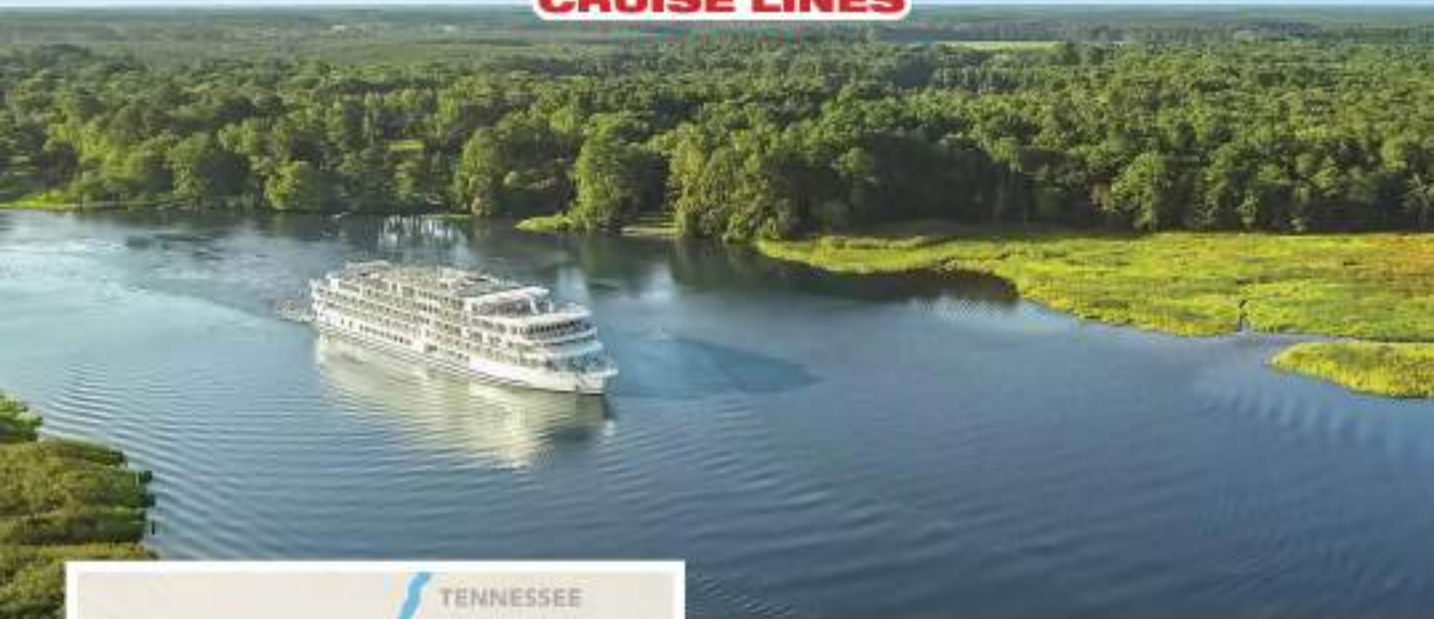


By production percentages, Chrysler Corp. cars were the stars of the '63 model year. Only Imperial lost ground—1.6 percent. Dart more than doubled production and Plymouth, Valiant and Dodge gained one fourth to one third over the '62 run. Valiant moved up from 16th place to 12th.

With a few thousand '63s around the country still unsold, final sales figures aren't in. All will be sold eventually, however, so production totals are a reasonable gauge of a model's success.

Chevrolet and Ford still lead the parade, but Falcon fell from third to sixth place. The full-sized Ford, which lost 11 percent with the '62s, reversed its field and picked up about 20 percent.

For their own purposes, manufacturers sometimes choose to lump together totals for various models. Our Buick figures, therefore, include Riviera. Similarly, Chevrolet includes Corvette. Studebaker production dropped almost 20 percent, but there's no indication of which models fared worst. Company production is lumped together. Even so, the total is in 23rd place. Unaided by its sisters, Lark alone held down 22nd place during the 1962 run.



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